Vol. XXVI, Part I. MARCH, 1956.

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

सत्यमेव जयते

THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI.

Vol. XXVI, Part I

March, 1956

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority

of

The Indian Council of Agricultural Research

सत्यमेव जयते

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 4 or 6s. 6d.

THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH,
NEW DELHI

ICAR. 5. XXVI. I
1,125

CONTENTS

Vol. XXVI, Part I

(March 1956)

Original Articles

Reviews

R

ORIGINAL ARTICLES.

SYSTEMATICS OF ORIENTAL TERMITES (ISOPTERA). No. 3.

ZOOLOGICAL SURVEY OF INDIA COLLECTIONS FROM INDIA AND BURMA, WITH NEW TERMITES OF THE GENERA *PARRHINOTERMES*, *MACROTERMES*, *HYPOTERMES* AND *HOSPITALITERMES**

By M. L. Roonwal, M.Sc. Ph.D., Chief Research Officer (Forest Entomologist) and P. K. Sen-Sarma, M.Sc., Junior Research Officer, Forest Research Institute, Dehra Dun

(Received for publication on April 21, 1955)

(With 9 text-figures)

THROUGH the courtesy of Dr S. L. Hora, Director, Zoological Survey of India, Calcutta, a valuable collection of oriental termites, belonging to the Survey, was made available to us for systematic study. The collection covered a wide area of the Indian mainland together with some of the Indian Ocean islands and there was also a small but interesting lot from Burma. The details of the localities of collection are as below :

1. India

(*a*) *Mainland*

1. *Bengal :* 1. Calcutta. 2. Jairampur, near Calcutta
2. *Madhya Pradesh* (formerly Central Provinces) (R. Nerbudda Survey) : 1. Low Hills near Bichhia, Mandla District. 2. Pachmarhi, 3500 ft.
3. *Madras State :* 1. Shevaroy Hills. 2. Chitteri, 3000 ft., Salem District. 3. Benkope Nilgiri Hills. 4. Tope, 500 ft. at foot of Palni Hills
4. *North-East Frontier Agency* (Assam) : Bank of Nong Priang River, Khasi Hills
5. *Orissa State :* 1. Barkuda Island, Chilka Lake. 2. Chahala *sal* jungle, 14 miles east of Joshipur (Mayurbhanj area)
6. *Vindhya Pradesh* (formerly in Central India States) : 1. " Sarai (land) " 2700 ft. (in former Rewa State). 2. Hill near Koilari, 2700 ft. (in former Rewa State)

(*b*) *Indian Ocean islands* (*Bay of Bengal*)

7. *Nicobar Islands :* Camorta Islands'
8. *Andaman Islands :* Port Blair : South of creek near S. Corbyn's Cave

2. Burma

Upper Burma : (Myitkyina District). 1. Loimon 2. Hopin

North Shan State : Namhkam

Three families, and 19 species and subspecies are represented in the collection. Of these, four new termites, viz.

Parrhinotermes khasii Roonwal and Sen-Sarma,

Macrotermes serrulatus hopini Roonwal and Sen-Sarma,

Hypotermes nongpriangi Roonwal and Sen-Sarma, and

Hospitalitermes blairi Roonwal and Sen-Sarma

have been described. The genus *Parrhinotermes* has been recorded for the first time from India.

*Work financed by the Indian Council of Agricultural Research under the Termites Research Scheme (Taxonomy).

The following is a list of the species represented in the collection, the castes present being mentioned within square brackets, thus : Im.-imago ; Ny., nymphs ; S.-soldiers ; and W.-workers :

(A) Family Kalotermitidae

1. *Neotermes* sp. [Im.]
2. *Cryptotermes dudleyi* (Banks). [Im.]

(B) Family Rhinotermitidae

Subfamily (i) Coptotermitinae

3. *Coptotermes heimi* (Wasm.). [Im.)
4. *Coptotermes travians* (Haviland). [S.]

Subfamily (ii) Rhinotermitinae

5. *Parrhinotermes khasii* Roonwal and Sen-Sarma (sp. nov.). [S., W.]

(C) Family Termitidae

Subfamily (i) Amitermitinae

6. *Speculitermes cyclops* (Wasmann). [W.]
7. *Microcerotermes annandalei* Silvestri. [S. ,W.]

Subfamily (ii) Termitinae

8. *Capritermes incola* (Wasmann). [S., W.]
9. *Capritermes obtusus* Silvestri. [Im., S., W.]

Subfamily (iii) Macrotermitinae

10. *Macrotermes annandalei* (Silvestri). [S., W.]
11. *Macrotermes estherae* (Desneux). [Im., S., W.]
12. *Macrotermes serrulatus hopini* Roonwal and Sen-Sarma (subsp. nov.). [S.,W.].
13. *Macrotermes serrulatus serrulatus* Snyder. [S., W.]
14. *Hypotermes nongpriangi* Roonwal and Sen-Sarma (sp. nov.). [S., W.]
15. *Microtermes anandi* Holmgren. [S., W.] (Syn. *Microtermes obesi* Holmg.)

Subfamily (iv) Nasutitermitinae

16. *Nasutitermes matangensis matangensiformis* (Holmgren). [S., Ny.]
17. *Hospitalitermes blairi* Roonwal and Sen-Sarma (sp. nov.). [S., W.]

18. *Trinervitermes biformis* (Wasmann). [S., W.]
19. *Trinervitermes heimi* (Wasmann). [S., W.]

Systematic Account

(A) Family Kalotermitidae

1. *Neotermes* sp.

(*a*) Material

Tube No. 44. One winged adult (female). "Barkuda Island, Chilka Lake, Ganjam District, Madras Presidency" (now in Orissa State), 20.i.1923. At light.

(*b*) Measurements (in mm.)

One winged adult (female) measured as follows :

1. Total body-length with wings	14
2. Body-length without wings	7
3. Length of fore-wing	12
4. Length of head to base of mandibles	1·92
5. Max. width of head (including eyes)	1·62
6. Length of pronotum	0·78
7. Max. width of pronotum	1·68

(*c*) Remarks

Wing venation is extremely variable. Veins of the fore-wing of right side differ from those of the left as follows : The cubitus of the fore-wing of right side runs high up in the wing-membrane, bends up and unites with the radial sector at the hind end like the cubitus of the fore-wing of the subgenus *Paraneotermes* (Light 1937)*; but the cubitus of the fore-wing of left side runs medially, does not bend to meet the radial sector. Hence, specific identification has not been possible.

2. *Cryptotermes dudleyi* (Banks)

(*a*) Material

Tube No. 51. Winged adults. "Barkuda Island, Chilka Lake, Ganjam District, Madras Presidency" (now in Orissa State), 18.iii.1924. At light.

(*b*) Measurements (in mm.)

Three winged adults measured as follows :

1. Total length of body with wings	8·5—9·0
2. Length of body without wings	5·0—5·0
3. Length of fore-wing	6·0—6·5
4. Length of head to base of mandibles	1·38—1·44
5. Max. width of head (including eyes)	0·90—0·90
6. Length of pronotum	0·60—0·72
7. Max. width of pronotum	0·90—0·96

*Light, S. L. (1937). *Univ. California Publ. (Ent.)*, Berkeley, 6 (16), p. 449.

(*c*) Remarks

Cryptotermes dudleyi (Banks) was previously recorded from neotropical, oriental and Australian regions. In the oriental region, it was recorded from Ceylon, Java and the Philippines*. The species is quite variable. In the present specimens, the median vein in the fore-wing unites with the radial sector in or near the middle of the wing and not beyond, as in typical *dudleyi*. However, since the wings of *C. dudleyi* exhibit a wide range of variability, we consider the difference stated above as individual variation.

(B) Family Rhinotermitidae

Subfamily (i) Coptotermitinae

3. *Coptotermes heimi* (Wasmann)

(*a*) Material

Tube No. 45. Winged adults. "Barkuda Island, Chilka Lake, Ganjam District, Madras Presidency" (now in Orissa State), "during slight shower". Coll. *N. Annandale*, 13.v.1923. At light.

Tube No. 93. Winged adults. Calcutta (Bengal). Coll. *S. Ribeiro*, 8.ii.1923. At light. "First appearance in year".

(*b*) Measurements (in mm.)

A few winged adults measured as follows, the number of specimens measured being given within square brackets:

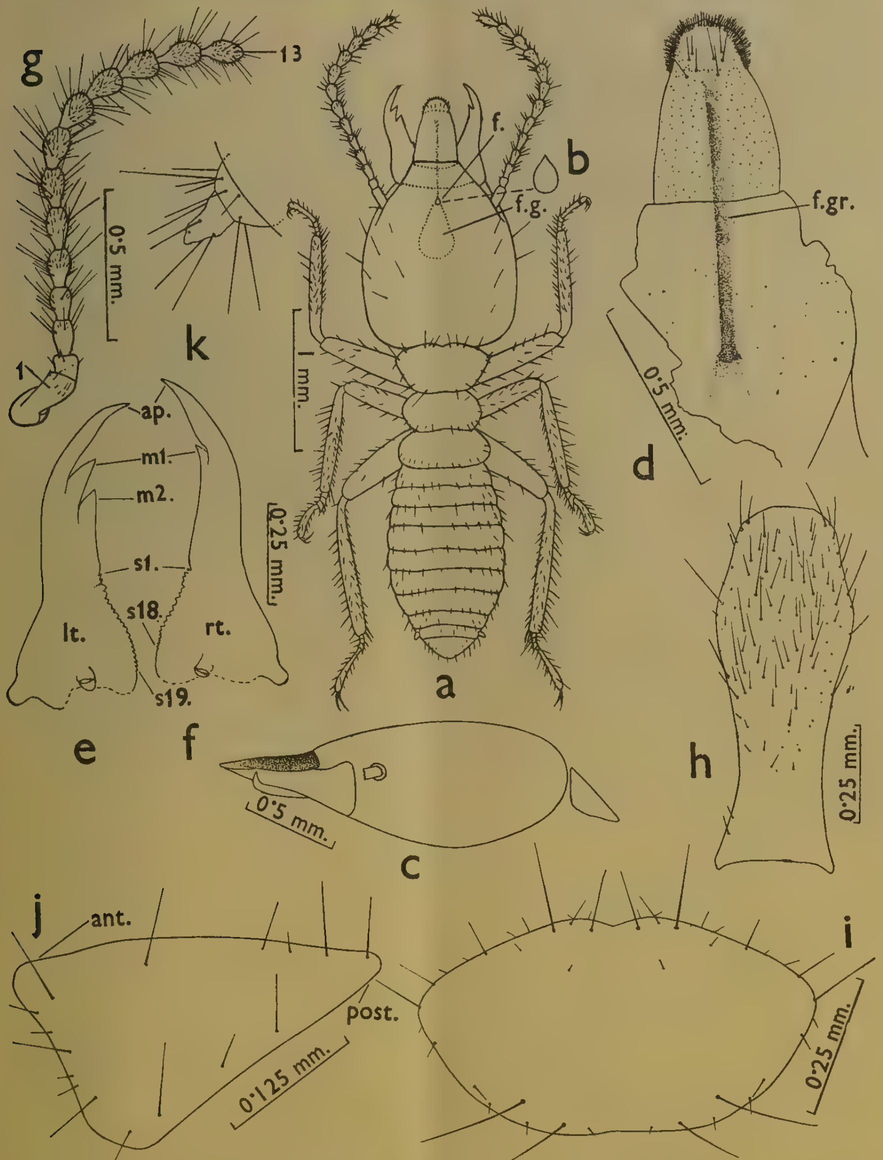
	Barkuda Is.	Calcutta
1. Total length of body with wings	9·5—11·0[4]	12·0—12·0[2]
2. Length of body without wings	5·94—6·03[4]	6·03—6·21[2]
3. Length of fore-wing	8·5—9·0[4]	10·90—10·90[2]
4. Length of head to base of mandible	1·38—1·44[4]	1·44—1·50[2]
5. Max. width of head (including eyes)	1·26—1·38[4]	1·50—1·50[2]
6. Length of pronotum	0·72—0·84[4]	0·72—0·78[2]
7. Max. width of pronotum	1·14—1·32[4]	1·38—1·44[2]

4. *Coptotermes travians* (Haviland)

(*a*) Material

Tube No. 63. Several soldiers. Jairampur, Calcutta. From rotten log of palm. *A. P. Kapur* Coll., 2.iv.1950.

*While this paper was in press we came across a paper by Chaudhry, G. U. (1955, *Pakistan J. Forest*, Abbottabad, 5 (1), p40) who records it from Khulna (East Bengal).



TEXT-FIG. 1. *Parrhinotermes* khasii Roonwal and Sen-Sarma (sp. nov.). Soldier.

(*a*) Whole soldier, in dorsal view. (*b*) Fontanelle, enlarged. (*c*) Head and pronotum, in side view (left). (*d*) Labrum with a portion of clypeus and frons. (Slide No. 105). (*e*) Left mandible, in dorsal view. (Slide No. 105). (*f*) Right mandible in dorsal view. (Slide No. 105). (*g*) Antenna of right side. (Slide No. 105). First and last segments numbered. (*h*) Postmentum. (Slide No. 105). (*i*) Pronotum, in dorsal view. (Slide No. 105). (*j*) Pronotum, in side view (left). (*k*) Cercus, with a portion of the abdominal segment.

Ant., anterior ; *ap.*, apical teeth of mandibles ; *f.*, fontanelle ; *f.g.*, fontanelle gland ; *f. gr.*, fontanelle groove ; *lt.*, left; *m1.*, *m2.*, 1st and 2nd marginal teeth of mandibles; *post.*, posterior; *rt.*, right ; *s1.—s19.*, 1st to 19th marginal serrations of mandibles.

(*b*) Measurements (in mm.)

Four soldiers measured as follows :

1. Total length of body	4·02—4·92
2. Length of head with mandibles	2·04—2·22
3. Length of head to base of mandibles	1·20—1·38
4. Max. width of head	1·02—1·14
5. Length of pronotum	0·36—0·42
6. Max. width of pronotum	0·72—0·72

Subfamily (ii) Rhinotermitinae

5. *Parrhinotermes khasii* Roonwal and Sen-Sarma (sp. nov.)

(Table I ; and Text-figs. 1 and 2)

(*a*) Material

In spirit, in vial No. 20*a* [now separated as No. 20*a*(i)], in the collection of the Zoological Survey of India, Calcutta, with a few soldiers and workers, found under bark of a dead tree on the bank of the Nong-priang stream, Khasi Hills, North-East Frontier Agency (Assam), altitude 1200 ft. above sea level. Coll. *S. L. Hora*, 20.xi.1923, at Survey Station No. 14. Material in vial found mixed with two other species, namely, *Odontotermes* sp. and *Hypotermes nongpriangi* sp. nov. (*vide infra*), both now separated in vial Nos. 20*a*(iii) and 20*a*(ii) respectively.

(*b*) Description

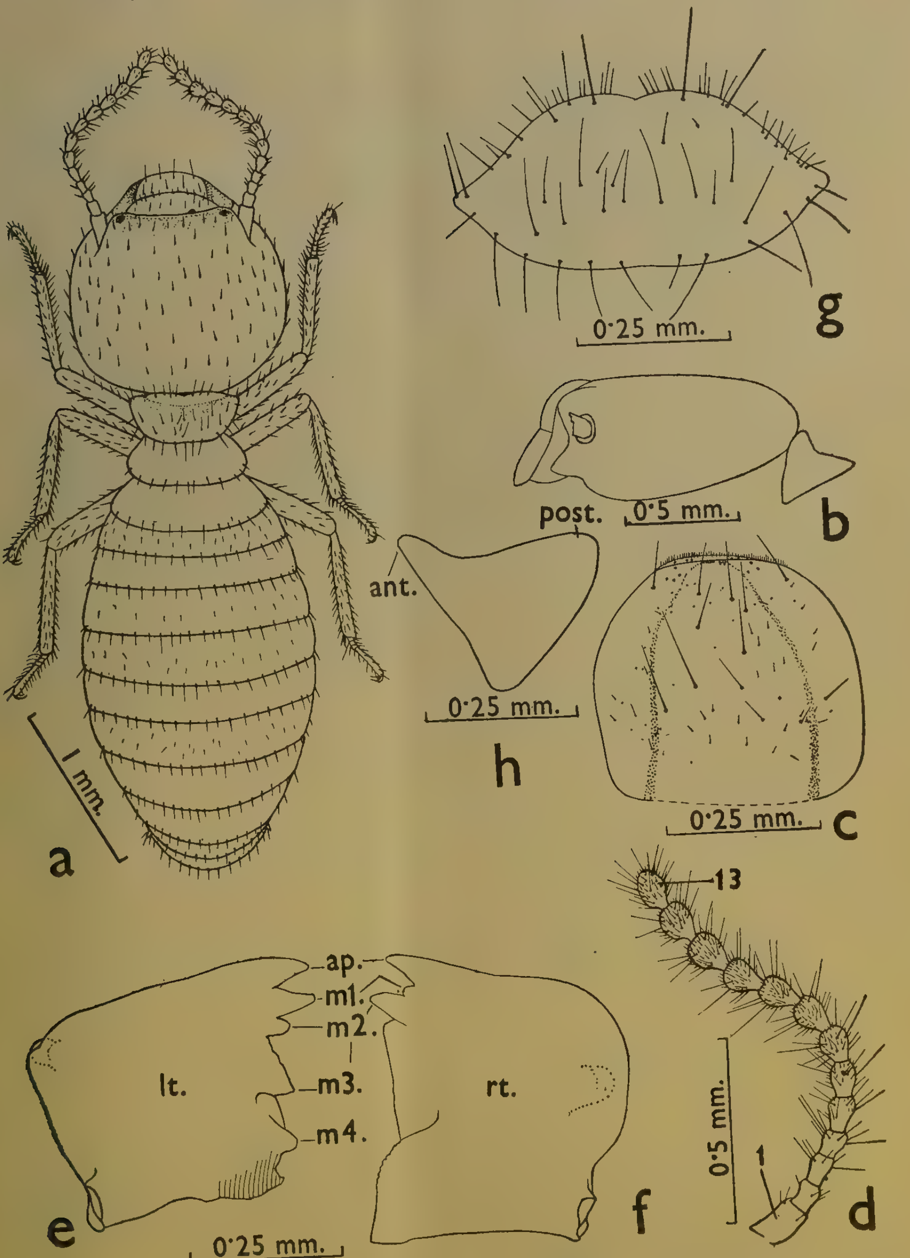
(Text-figs 1 and 2)

1. Imago Unknown.

2. Soldier (Text-fig. 1)

General : Usually smaller than workers. Length of head with mandible only slightly smaller than rest of body. Head yellowish brown ; body and legs pale yellow; mandibles darker than head, blackish at tips. Body elongate and rather slender except for the head. Entire body, including head, pilose. Approximate length of body (including mandibles) 3·87-4·23 mm.

Head : Yellowish brown ; broad, flat and squarish, with narrow anterior end ; broadest in middle ; hind angles rounded. With a few bristles and microscopic hairs. Fontanelle small, pear-shaped, lying near clypeus and opening into a narrow groove leading to base of hyaline tip of labrum. Fontanelle gland rather large and fusiform. Postclypeus small, flat ; anteclypeus narrower, whitish. *Antennae :*



TEXT FIG. 2. *Parrhinotermes Khasii* Roonwal and Sen-Sarma (sp. nov.) Worker.

(*a*) Whole worker, in dorsal view. (*b*) Head and pronotum, in side view (left). (*c*) Labrum, in dorsal view. (Slide No. 104). (*d*) Right antenna. (Slide No. 104). First and last segments numbered. (*e*) Left mandible, in dorsal view. (Slide No. 104). (*f*) Right mandible, in dorsal view. (Slide No. 104). (*g*) Pronotum, in dorsal view. (Slide No. 104). (*h*) Pronotum, in side view (left).

ant., anterior ; *ap.*, apical teeth of mandibles ; *lt.*, left ; *m1.—m4.*, 1st to 4th marginal teeth of mandibles ; *Post* posterior ; *rt.*, right.

with 13 segments, all pilose, with 3-4 long bristles (as long as the length of the segments) and a few smaller ones. Each segment, except the last two, club-headed, narrow proximally and wide distally; the last two segments with nearly parallel sides. Segment 1 longest; segment 2 smallest; segments 3 and 4 longer than 2 and subequal; thereafter, the segments slightly but appreciably larger as we go distally, but last (13th) segment again narrower and smaller than segments 5-12. *Eyes :* Absent. *Labrum* : Elongate, about 1·7 times as long as broad; finger-shaped, with a slight constriction at junction of blunt rounded tip and main body; nearly fully covering the mandibles; hyaline tip with a dense row of fine bristles at the margin, and 3-4 long bristles on either side of the area. *Mandibles :* Dark brown at base; smoky brown at tip. Long, sabre-shaped, the tip sharply pointed, followed by 1-2 deep indentations for teeth; the inner proximal one-third margin finely serrated, with about 18-19 serrations (18 in right and 19 in left mandible); the serrations deeper distally, less so proximally. Left mandible with 2, the right with 1, indentations which are deeper in left than in right mandible. First marginal tooth of left mandible rather large, pointed, triangular and not leaf-shape; nearly opposes the single tooth on right mandible. Tooth on right mandible sharp, pointed, forming a sharply defined acute angle with mandible and placed beyond outer third towards tip. (Also see below under Comparisons). *Postmentum :* Long; shorter than head. With a bulge in anterior one-third, then with the sides sloping in, and then bulging out again; anterior margin convex; posterior margin slightly concave; anterior half with numerous short bristles in longitudinal rows and pointing forward.

Thorax : Pronotum : Flat; trapezoid; with anterior margin longer than posterior; straight (not saddle-shaped) in side view. Anterior margin convex, with a sharp median notch. Posterior margin nearly straight, with a shallow median notch. The angles, especially posterior ones, rounded with a few long bristles and smaller hairs near anterior margin and elsewhere. *Legs :* Femora tibiae and tarsi: all slender. Tibia and tarsus with numerous bristles. Distal end of tibiae with two straight hooks (somewhat shorter than claws) on the inside. Tarsi 4-segmented; segments 1-3 short and subequal; 4 (distal) longest (about thrice as long as the remaining 3 put together) and ending in two rather long, curved claws.

Abdomen : Fairly heavily pilose at the posterior end, but lightly so elsewhere. With 10 terga and 7 sterna. Paired cerci short, 2-segmented (with a broad basal and an elongated terminal segment, the latter with a constriction in middle) and bristled; placed laterally in between 9th tergum and 7th visible sternum.

Measurements. See Table I.

3. Worker (Text fig. 2)

General : Usually much larger than soldiers.

Head : Pale yellow, rounded, flattened dorso-ventrally; uniformly pilose, with short, fine, microscopic hairs. With a pair of small swellings in clypeal region, the swellings flanked by a dark area. Fontanelle not seen. Eyes absent. Labrum squarish, with distal end narrower and broadly rounded; with subparallel sides;

TABLE I

Parrhinotermes khasii *Roonwal and Sen-Sarma (sp. nov.) . Body-measurements (in mm.) and indices of soldiers*

Body-parts	Range	Holotype (Soldier)
I. GENERAL.		
1. Length of body	3·87—4·23	4·14
II. HEAD.		
2. Length of head to lateral base of mandible	1·20—1·32	1·26
3. Max. width of head	1·02—1·14	1·08
4. Max. height of head	0·66—0·78	0·78
5. Head Index I. (Width/Length)	0·86—0·90	0·86
6. Head Index II. (Height/Length)	0·55—0·62	0·62
7. Head Index III. (Height /Width)	0·63—0·72	0·72
8. Fontanelle Index (Head-length to fontanelle Head-length to base of mandible)	0·82—0·90	0·86
9. Length of right mandible	0·66—0·78	0·72
10. Length of left mandible	0·66—0·78	(tip broken)
11. Length of labrum (without terminal bristles)	0·48—0·48	0·48
12. Max. width of labrum	0·30—0·36	0·30
13. Labrum Index (Width/Length)	1·30—1·60	1·60
14. Length of postmentum	0·90—1·08	0·96
15. Max. width of postmentum	0·30—0·36	0·30
16. Min. width of postmentum	0·18—0·18	0·18
17. Postmentum Index I. (Max. width/Length)	0·31—0·40	0·31
18. Postmentum Index II. (Min. width/Length)	0·17—0·20	0·19
19. Postmentum Index III. (Min. width/Max. width)	0·50—0·60	0·60
III. THORAX.		
20. Length of pronotum	0·36—0·48	0·36
21. Max. width of pronotum	0·66—0·72	0·72
22. Pronotum Index (Length/Width)	0·50—0·73	0·50

with a few large bristles on dorsal surface and a dense row of very fine, microscopic hairs at distal margin; with a loop of fine sensillae ventrally. *Antennae:* With 13 segments; comparative size of segments as in soldier. *Mandibles:* Short stout and squarish; dark brown with the margins smoky brown to black. Right mandible with a prominent apical tooth, a very small 1st marginal and a prominent 2nd marginal tooth; followed by a long smooth margin and then an equally long finely serrated margin. Left mandible with a well developed apical tooth, the 1st marginal tooth laterally projecting beyond the apical; the 2nd marginal small; and the 3rd and 4th marginals prominent, followed by a tooth-like molar area.

Thorax: Pronotum: Saddle-shaped, rather pilose, nearly half as broad as head; anterior border prominently incised in middle; posterior border comparatively straight. *Meso*—and *metanota:* Much broader than pronotum; rather flat; pilose.

Measurements (in mm.):

1. Total body-length	4·41—4·77
2. Length of head to lateral base of mandibles	1·02—1·14
3. Max. width of head	1·14—1·2
4. Max. height of head	0·78—0·9
5. Length of labrum	0·42—0·42
6. Max. width of labrum	0·42—0·42
7. Length of pronotum	0·24—0·3
8. Max. width of pronotum	0·60—0·66

(*c*) Type-specimens

All material from a single source (see above). (i) *Holotype* and *morphotype:* One holotype soldier and one morphotype worker, in spirit in a single vial, No. 20*a*(i), deposited in the Zoological Survey of India, Calcutta. Coll. *S. L. Hora*, 20th Nov. 1923. In holotype, the tip of left mandible broken; terminal segment of both the antennae missing due to injury; hind-leg of right side injured; measurements in Table I. (ii) *Paratypes and paramorphotypes* from type colony: Deposited as follows: (*a*) Zoological Survey of India, Calcutta, thus: One paratype soldier and one paramorphotype worker on a single slide (No. 106 of F. R. I.). Also several paramorphotype workers in spirit in a vial. (*b*) Forest Research Institute, Dehra Dun: One paratype soldier and 3 paramorphotype workers, in spirit, in a single vial. (Regd. No. 18651). Also, one paratype soldier body-parts on slide No. 105; and one paramorphotype worker body-parts on slide No. 104. (*c*) with Prof. Alfred E. Emerson, Chicago University, Chicago, U.S.A.: One paratype soldier and one paramorphotype worker in spirit in a single vial.

(*d*) Type-locality

Zoological Survey of India Collecting Station No. 14, bank of R. Nong-priang, Khasi Hills, North-East Frontier Agency (Assam), *cd.* 1200 ft. above sea level.

(*e*) Type-host

Under bark of dead tree of an unknown species.

(*f*) Geographical distribution

Khasi Hills (Assam, India), 1200 ft. above sea level. Known only from the type-locality. This is the first record of the genus *Parrhinotermes* from India.

(*g*) Comparisons

The new species belongs to the group of *Parrhinotermes* in which the 1st marginal tooth (the anterior tooth or 'Vorderzahn' of Holmgren (*Kungl. Sv. Vet. Akad. Handl.*, Stockholm, Vol. 50, No. 2, 1913, pp. 78-79, key) of the left mandible is triangular and not leaf-shaped as in *P. inaequalis* Hav. The three species close to the new one, *P. khasii*, are *aequalis* Haviland, *buttel-reepeni* Holmgren and *qeenslandicus* Mjöberg. From these it differs in the structure of the soldier mandibles as follows :—*P. aequalis* Hav. alone has the 2nd marginal tooth of the left mandible very reduced (much smaller than the 1st marginal) and very close to the 1st marginal. *P. khasii* differs from *buttel-reepeni* Holmg. and *queenslandicus* Mjöberg in having the 2nd marginal tooth of the left mandible and the 1st marginal of the right mandible separated widely from the 'base', i.e. from the distal end of the serrate inner base—this distance is the widest in *khasii* , much less so in the other two, and almost obliterated in *aequalis* Hav.

(C) Family Termitidae

Subfamily (i) Amitermitinae

6. *Speculitermes cyclops* (Wasmann)

(*a*) Material

Tube No. 5a. Mixed with *Odontotermes* sp., but now separated in Tube No. 5*a*(*a*). Workers only. Shevaroy Hills, Madras State. Z. S. I. Collecting Station. No. 11A.

Tube No. 71. Workers only. Low hills near Bichhia, Mandla District (misprinted on label as "Mandila Diet"), Madhya Pradesh, Z. S. I. Collecting Station No. 86. *H. S. Pruthi* coll. (Nerbudda Survey), 29.xi.1927.

Tube No. 72. Workers only. Pachmarhi, 3,500 ft., Madhya Pradesh, Z. S. I. Collecting Station No. 102. *H. S. Pruthi* coll. (Nerbudda Survey), 15.xii.1927.

Tube No. 90. Workers only. Chitteri, 3,000 ft. (Salem District, Eastern Ghats, Madras State). Z. S. I. Collecting Station No. 28. *H. S. Pruthi* coll., 22-26. vi.1929.

(*b*) MEASUREMENTS (in mm.)

Four workers [from Shevaroy Hills, in tube 5*x* (*a*)] measured as follows; specimens in other tubes are found dried up:

1. Total length of body	5·76—6·66
2. Length of head to base of mandibles	0·96—1·08
3. Max. width of head	1·32—1·38
4. Length of pronotum	0·42—0·42
5. Max. width of pronotum	0·78—0·84

7. *Microcerotermes annandalei* Silvestri

(*a*) MATERIAL

Tube No. Nil. Soldiers and workers. Z. S. I. Collecting Station No. 1, *sal* jungle at Chahala, 14 miles east of Joshipur, Simplipal Hills, Orissa. *Shaukat Ali* coll. (Mayurbhanj Survey), 8-II-1951.

(*b*) MEASUREMENTS (in mm.)

Three soldiers measured as follows:

1. Total length of body	4·86—5·13
2. Length of head with mandibles	2·64—2·70
3. Length of head to base of mandibles	1·80—1·80
4. Max. width of head	0·90—0·96
5. Length of pronotum	0·30—0·30
6. Max. width of pronotum	0·60—0·66

Subfamily (ii) Termitinae

8. *Capritermes incola* (Wasmann)

(*a*) MATERIAL

Tube No. 8a. Two soldiers and few workers. Benkope, Nilgiris, S. India. *S. L. Hora* coll., 22-X-1925.

(*b*) MEASUREMENTS (in mm.)

Two soldiers measured as follows:

1. Total length of body	7·03—7·47
2. Length of head with mandibles	4·05—4·14
3. Length of head to base of mandibles	2·25—2·25
4. Max. width of head	1·38—1·38
5. Length of pronotum	0·30—0·30
6. Max. width of pronotum	0·60—0·66

9. *Capritermes obtusus* Silvestri

(*a*) Material

Tube No. 10. Winged adults, soldiers and workers. "Barkuda Island, Chilka Lake, Ganjam District, Madras Presidency" (now in Orissa State). *N. Annandale* coll., 3-vi-1922.

Tube No. 47. Dealates and soldiers. Locality as in Tube No. 10. *N. Annandale* coll., 1922.

(*b*) Measurements (in mm.)

The number of specimens measured is indicated in square brackets.

——	Tube No. 10 (soldiers)	Tube No. 47 (soldiers)
1. Total length of body	6·12 [1]	6·21—6·39[2]
2. Length of head with mandibles	4·05—4·14[2]	4·05—4·14[2]
3. Length of head to base of mandibles	2·07—2·16[2]	2·07—2·16[2]
4. Max. width of head	1·26—1·32[2]	1·26—1·32[2]
5. Length of pronotum	0·30—0·30[2]	0·30—0·30[2]
6. Max. width of pronotum	0·66—0·66[2]	0·66—0·66[2]
	(*Alates*)	(*Dealates*)
1. Total length of body with wings	11·0—11·5[4]	..
2. Length of body without wings	6·0—7·0 [4]	6·0—7·0 [4]
3. Length of fore-wing	9·0—9·5 [4]	..
4. Length of head to base of mandibles	1·32—1·38[4]	1·38—1·44[4]
5. Max. width of head	1·20—1·26[4]	1·20—1·32[4]
6. Length of pronotum	0·54—0·60[4]	0·60—0·66[4]
7. Max. width of pronotum	0·96—1·02[4]	0·99—1·08[4]

Subfamily (iii) Macrotermitinae

10. *Macrotermes annandalei* (Silvestri)

(*a*) Material

Tube No. 15a. Soldiers (major and minor) and workers (major and minor). Loimon, a small village on the western shore of the Indawgyi Lake, Myitkyina Dist., Upper Burma. *B. Chopra* coll., 2-5-xi-1926.

(*b*) MEASUREMENTS (in mm.)

Four major and four minor soldiers measured as follows :

	Soldiers (major)	*Soldiers (minor)*
1. Total length of body	11·16—11·52	6·75—7·02
2. Length of head with mandibles	6·93—7·20	3·69—4·14
3. Length of head to base of mandibles	4·50—4·50	2·25—2·34
4. Max. width of head	3·60—3·87	1·98—2·04
5. Length of pronotum	1·26—1·35	0·72—0·81
6. Max. width of pronotum	2·34—2·61	1·35—1·44

11. Macrotermes estherae (Desneux)

(*a*) MATERIAL

Tube No. 9a. Winged adults (alates and dealates), soldiers (5 major and 1 minor) and workers (several major and a few minor). Tope, 500 ft., foot of Palni Hills, S. India. *S. Kemp* coll., 22-ix-1922.

(*b*) MEASUREMENTS (in mm.)

The number of specimens measured is indicated in square brackets.

	Imagos (alates and dealates)
1. Total length of body with wings	33·0 [1]
2. Length of body without wings	15·5—17·0[3]
3. Length of fore-wing	28·0 [1]
4. Length of head to base of mandibles	1·80—1·98[3]
5. Max. width of head (including eyes)	2·70—2·88[3]
6. Length of pronotum	1·44—1·62[3]
7. Max. width of pronotum	2·70—2·88[3]

	Soldiers (major)	Soldiers (minor)
1. Total length of body	11·97—13·32[4]	8·28[1]
2. Length of head with mandibles	5·85—6·39[4]	3·78[1]
3. Length of head to base of mandibles	4·23—4·32[4]	2·34[1]
4. Max. width of head	3·60—4·05[4]	2·07[1]
5. Length of pronotum	1·26—1·35[4]	0·90[1]
6. Max. width of pronotum	2·70—2·88[4]	1·62[1]

12. Macrotermes serrulatus hopini Roonwal and Sen-Sarma (subsp. nov.) (Table II ; and Text-figs. 3 and 4)

(*a*) Material

One vial (No. 10a), in spirit, in the collection of Zoological Survey of India, Calcutta, with a few soldiers (major) and workers (major). Found under rotten wood, at Hopin, Myitkyina District, upper Burma ; *B. Chopra* coll., 13-x-1926.

(*b*) Description (Text-figs. 3 and 4)

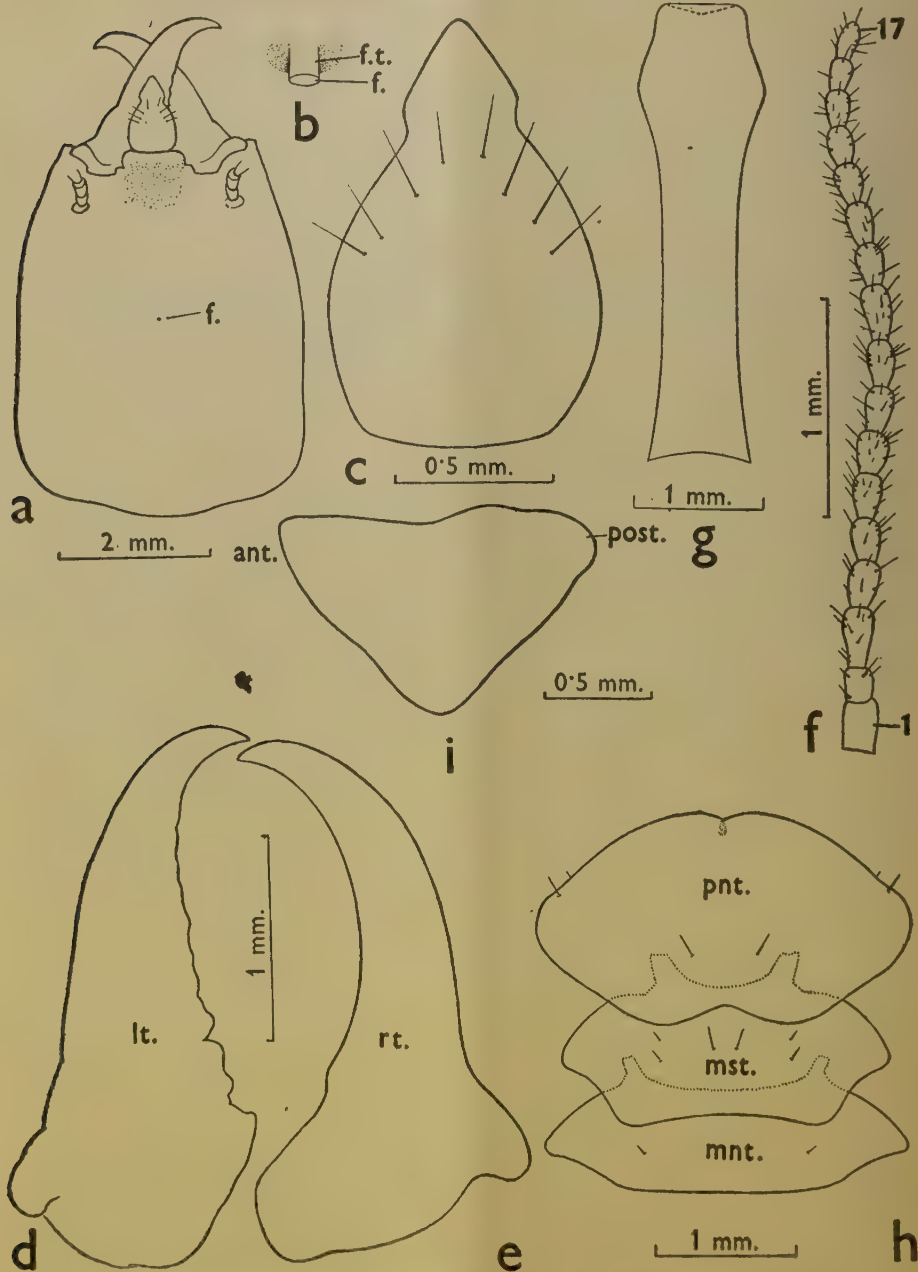
1. Imago—Unknown

2. Soldier (Major) (Text-fig. 3)

General : Size large. Length of head with mandibles usually subequal to or sometimes a little longer than rest of body. Head-capsule brown above and below, sometimes paler ; postmentum dark brown ; antennae brown, generally as dark as the head-capsule, sometimes a little darker. Labrum, excepting at the hyaline tip, as dark as head-capsule. Mandibles black. Legs light brown ; abdomen light to dark brown. Head and thorax mostly devoid of hairs ; abdomen and legs moderately pilose. Approximate length of body (including mandibles) 11·5-12·7 mm.

Head : Brown, large ; sub-rectangular, length more than breadth, broadest at the occiput, gradually narrowing anteriorly ; dorsally a little arched, ventrally flat. *Epicranial sutute* (Y-suture) : Absent. *Fontanelle :* Small, circular and situated a little ahead of the middle of the head-capsule ; leading to an anteriorly directed small dark brown tube. *Postclypeus* Subrectangular, a little raised from the rest of the head surface ; *Anteclypeus* Rectangular, whitish and not separable from postclypeus by any suture. *Antennae :* Arising distinctly from dorsum of head ; moderately pilose, with long, stout hairs ; with 17 segments, all elongated ; segment-1 longest and broadest ; segment-2 much smaller than 3 ; segment-3 longer than 4 ; segments 4-17 subequal. *Eyes :* Absent. *Labrum* : Pear shaped ; widest at posterior two-thirds ; with a triangular hyaline tip ; with 4 long hairs on either side of anterior half. *Mandibles :* Black almost throughout ; elongate, stout ; broadest basally and curved at tip. Left mandible with inner margin strongly serrated, undulating and with a relatively deep notch in the basal one-third portion. Right mandible with inner margin smooth. *Postmentum :* Long and slender ; shorter than head ; anterior portion broadest and with convex sides ; anterior margin transversely truncated ; posterior margin slightly concave.

Thorax : Pronotum : Saddle-shaped ; with numerous microscopic hairs on inner margin of anterior border, and with 3 or 4 short scattered hairs ; a little broader than half the length of head-width ; sides subconical ; anterior margin with a median notch ; posterior margin more deeply incised medially. *Mesonotum :* Bluntly conical at sides ; anterior margin shallowly concave medially, with two anteriorly directed lateral projections ; posterior margin with a broad and shallow median



TEXT-FIG. 3. *Macrotermes serrulatus hopini* Roonwal and Sen-Sarma (subsp. nov.). Soldier major.

(*a*) Head-capsule, in dorsal view. Only basal segments of antennae shown. (*b*) Fontanelle and the fontanelle tube, (enlarged). (*c*) Labrum, in dorsal view. (Slide No. 139). (*d*) Left mandible, in dorsal view. (Slide No. 139). (*e*) Right mandible, in dorsal view. (Slide No. 139). (*f*) Right antenna. First and last (17th) segments numbered. (*g*) Postmentum. (*h*) Thorax, in dorsal view, showing the pro-, meso- and metanota. (*i*) Pronotum, in side view (left).

ant., anterior ; *f.*, fontanelle ; *f.t.*, fontanelle tube ; *lt.*, left ; *mnt.*, metanotum ; *mst.*, mesonotum ; *pnt.*, pronotum ; *post.*, posterior ; *rt.*, right.

concavity; antero-lateral margins convex, postero-lateral margins concave; with a few minute hairs. *Metanotum:* Comparatively sharply conical at sides; shorter than mesonotum; anterior margin broadly concave, with two anteriorly directed lateral projections; posterior margin straight, antero-lateral margins convex, postero-lateral margins relatively shallowly concave; with a few minute hairs. *Legs:* Femora, tibiae and tarsi, all slender and elongated. Femora with a few long hairs; tibiae moderately pilose and also with strong spines linearly arranged on inner border; distal inner end of tibiae with two straight spines. Tarsi moderately pilose; 4-segmented; segments-1-3 short and subequal; segment-4 (distal) longest (about thrice as long as the remaining three put together) and ending in two rather long, curved claws.

Abdomen: Relatively short; densely pilose with short hairs arranged segmentally in rows; with 10 terga and 9 sterna. The paired cerci with a broad basal and an elongated terminal segment; with bristles.

Measurements—See Table II.

3. Soldier (Minor)—Unknown.

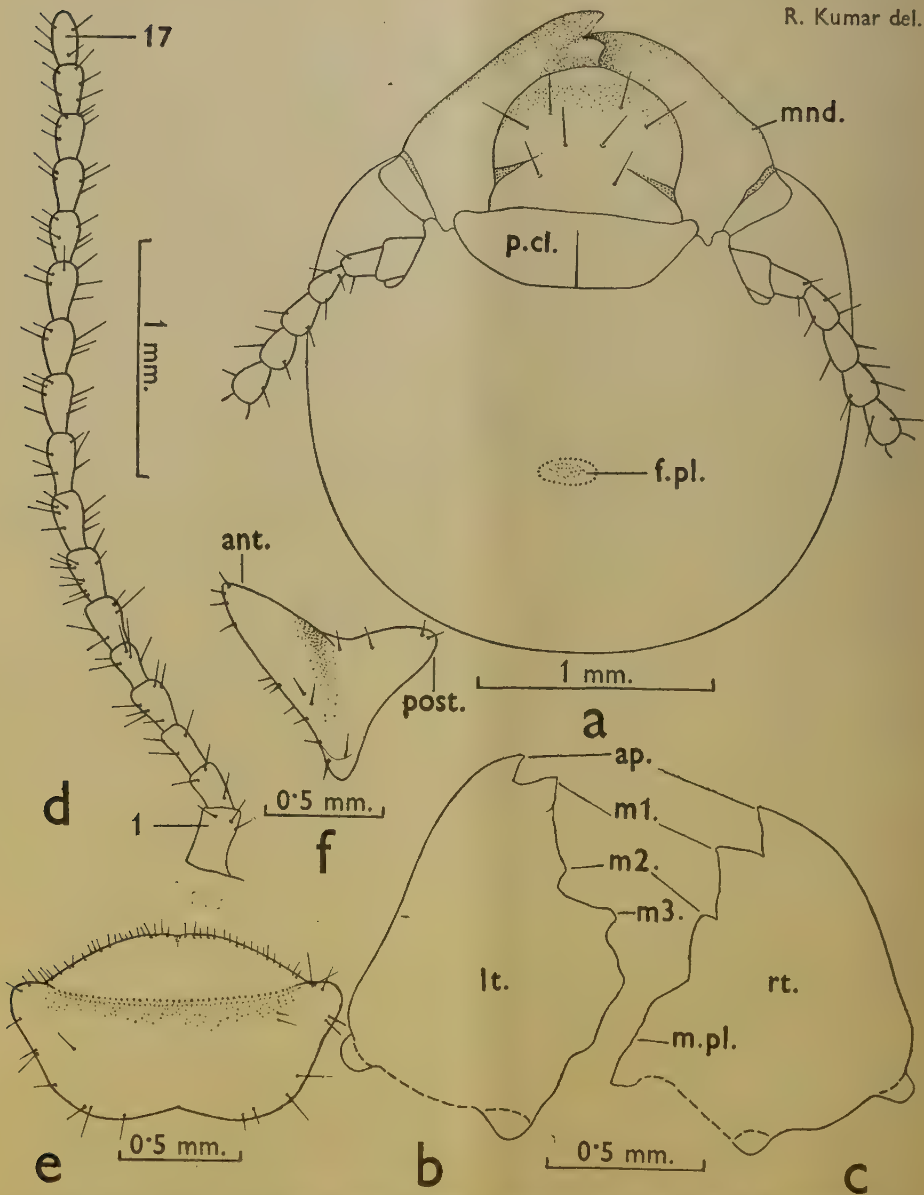
4. Worker (Major) (Text-fig. 4)

General: Head brown; clypeus, antennae and abdomen straw-coloured; thorax brownish, a little darker than abdomen but paler than head.

Head: Head-capsule nearly Subcircular a little broader than long (up to lateral base of mandibles). *Fontanelle:* covered with a white, shining, translucent, large and oval plate, situated a little behind middle of head-capsule. *Eyes:* Absent. *Antennae:* 17-segmented; segment-3 a little longer than 2 and subequal to 4; segment 5 smaller than 4 and 6; other remaining segments subequal. *Postclypeus:* Greatly swollen and medially divided by a dark longitudinal line. *Anteclypeus:* Not visible. *Labrum:* Short : not covering the length of mandibles; squarish, nearly as long as broad, sometimes a little longer; anterior margin rounded; sides subparallel, with a fold in basal third; tip hyaline. *Mandibles:* Stout; brownish; their inner margins very dark. Left mandible with one apical and 3 well-defined marginals; 1st marginal projecting a little beyond the apical; 2nd marginal low and conical; 3rd marginal elongated. Right mandible with one apical, and 2 marginal teeth; also with a molar plate; 1st marginal tooth well developed, conical; 2nd marginal low and blunt.

Thorax: Pronotum: Saddle-shaped; nearly half the width of head; anterior margin with very shallow medial concavity; posterior margin deeply notched in middle; moderately pilose. Mesonotum narrower and metanotum broader than pronotum; pilose.

Abdomen: With 10 terga and 9 sterna. Cerci as in soldier.



TEXT-FIG. 4. *Macrotermes serrulatus hopini* Roonwal and Sen-Sarma (subsp. nov.). Worker major.

(*a*) Head-capsule, in dorsal view. Only basal segments of antennae shown. (*b*) Left mandible, in dorsal view. (Slide No. 140.) (*c*) Right mandible, in dorsal view. (Slide No. 140.) (*d*) Right antenna. First and last (17th) segments numbered. (*e*) Pronotum, in dorsal view. (*f*) Pronotum, in side view (left).

ant., anterior; *ap.*, apical teeth of mandibles; *f.pl.*, fontanelle plate; *lt.*, left; *m1.—m.3*, 1st to 3rd marginal teeth of mandibles; *mnd.*, mandible; *m. pl.*, molar plate; *p.cl.*, postclypeus; *post.*, posterior; *rt.*, right.

TABLE II

Macrotermes serrulatus hopini Roonwal and Sen-Sarma (subsp. nov.). *Body-measurements (in mm.) and indices of major soldiers*

Body-parts	Number of specimens measured	Range	Holotype (soldier, major)
I.—GENERAL			
1. Length of body	5	11·52—12·69	11·97
II.—HEAD			
2. Length of head to lateral base of mandible	5	4·68—4·86	4·77
3. Max. width of head	5	3·78—3·96	3·78
4. Max. height of head	5	2·52—2·70	2·70
5. Head Index I (Width/Length)	5	0·79—0·83	0·79
6. Head Index II (Height/Length)	5	0·53—0·57	0·57
7. Head Index III (Height/Width)	5	0·66—0·71	0·71
8. Fontanelle Index (Head-length to fontanelle/Head-length to base of mandible).	5	0·56—0·59	0·57
9. Length of right mandible	5	2·07—2·34	2·25
10. Length of left mandible	5	2·16—2·34	2·35
11. Length of labrum (without terminal bristles)	5	0·81—0·99	0·81
12. Max. width of labrum	5	0·81—0·90	0·81
13. Labrum Index (Width/Length)	5	0·90—1·0	1·0
14. Length of postmentum	5	3·06—3·42	3·06
15. Max. width of postmentum	5	0·90—0·99	0·99
16. Min. width of postmentum	5	0·63—0·72	0·72
17. Postmentum Index I (Max. width/Length)	5	0·26—0·32	0·32
18. Postmentum Index II (Min. width/Length)	5	0·18—0·23	0·23
19. Postmentum Index III (Min. width/Max. width)	5	0·64—0·73	0·73
III.—THORAX			
20. Length of pronotum	5	1·35—1·44	1·35
21. Max. width of pronotum	5	2·52—2·70	2·70
22. Pronotum Index (Length/Width)	5	0·50—0·55	0·50
23. Max. width of mesonotum	5	2·16—2·43	2·16
24. Max. width of metanotum	5	2·25—2·52	2·25

Measurements (in mm.)

1. Total length of body	6·84—7·65
2. Length of head to lateral base of mandibles	1·89—2·07
3. Max. width of head	2·16—2·34
4. Max. height of head	0·90—0·96
5. Length of labrum	0·45—0·63
6. Max. width of labrum	0·63—0·81
7. Length of pronotum	0·72—0·90
8. Max. width of pronotum	1·17—1·35

5. WORKER (MINOR)—Unknown

(c) TYPE-SPECIMENS

All specimens from a single source (see above). (i) *Holotype* and *morphotype :* One holotype soldier and one morphotype worker, in spirit, in a single vial, No. 10a. Deposited in the Zoological Survey of India, Calcutta. In the holotype, the middle and hind-legs of the right side and the left antenna are broken. For measurements of holotype soldier see Table II.

(ii) *Paratypes* and *paramorphotypes* (from type colony) : Deposited as follows : (*a*) Zoological Survey of India, Calcutta, thus : one paratype soldier and 3 paramorphotype workers in spirit in a single vial. (*b*) Forest Research Institute, Dehra Dun : One paratype soldier and 4 paramorphotype workers, in spirit, in a single vial. (Regd. No. 19868) and one paramorphotype worker mandibles on slide No. 140. Also slide Nos. 139 and 145 of body-parts of paratype soldiers. (*c*) Prof. Alfred E. Emerson, Chicago University, Chicago, U. S. A. : One paratype soldier and one paramorphotype worker, in spirit, in a single vial.

(d) TYPE-LOCALITY

Hopin, Myitkyina District, Upper Burma.

(e) TYPE-HOST

Under rotten wood of an unknown species.

(f) GEOGRAPHICAL DISTRIBUTION

Known only from the type locality.

(g) COMPARISONS

The new subspecies belongs to the group of *Macrotermes* in which the sides of meso- and metanota are more or less conical and not rounded as in *M. gilvus* (Hagen).

From *M. serrulatus serrulatus* Snyder, it differs in the following respects : (i) Head paler. (ii) Postmentum with the distal part (anterior to the broadened portion) broader. (iii) Pronotum with the median notch in the anterior margin deeper (iv) Mesonotum and metanotum with the postero-lateral margins concave (not straight or slightly convex as in *M. serrulatus serrulatus*).

13. Macrotermes serrulatus serrulatus Snyder

(*a*) Material

Tube No. 14a.—One soldier (minor) and 3 workers. Rice-fields and channels round about Namhkam, North Shan States, Burma, *ca.* 2,500 ft. *H. S. Rao* coll. November, 1926.

(*b*) Measurements (in mm.)

The single minor soldier measured as follows :

1. Total length of body	8·19
2. Length of head with mandibles	4·23
3. Length of head to base of mandibles	2·70
4. Max. width of head	2·07
5. Length of pronotum	0·99
6. Max. width of pronotum	1·53

14. Hypotermes nongpriangi Roonwal and Sen-Sarma (sp. nov.)

(Table III ; and Text-fig. 5 and 6.)

(*a*) Material

One soldier and 5 workers in spirit, in vial No. 20*d*, now separated as No. 20*a* (ii), mixed with soldiers and workers of *Parrhinotermes khasii* Roonwal & Sen-Sarma (*vide supra*) and *Odonototermes* sp. [now separated as vial No. 20*a* (iii)], *S. L. Hora* coll. 20-XI-1923. Under bark of a dead tree-trunk, at Survey Station No. 14 on the bank of R. Nong-priang Khasi Hills North-East Frontier Agency (Assam) ; altitude 1,200 ft. above sea-level.

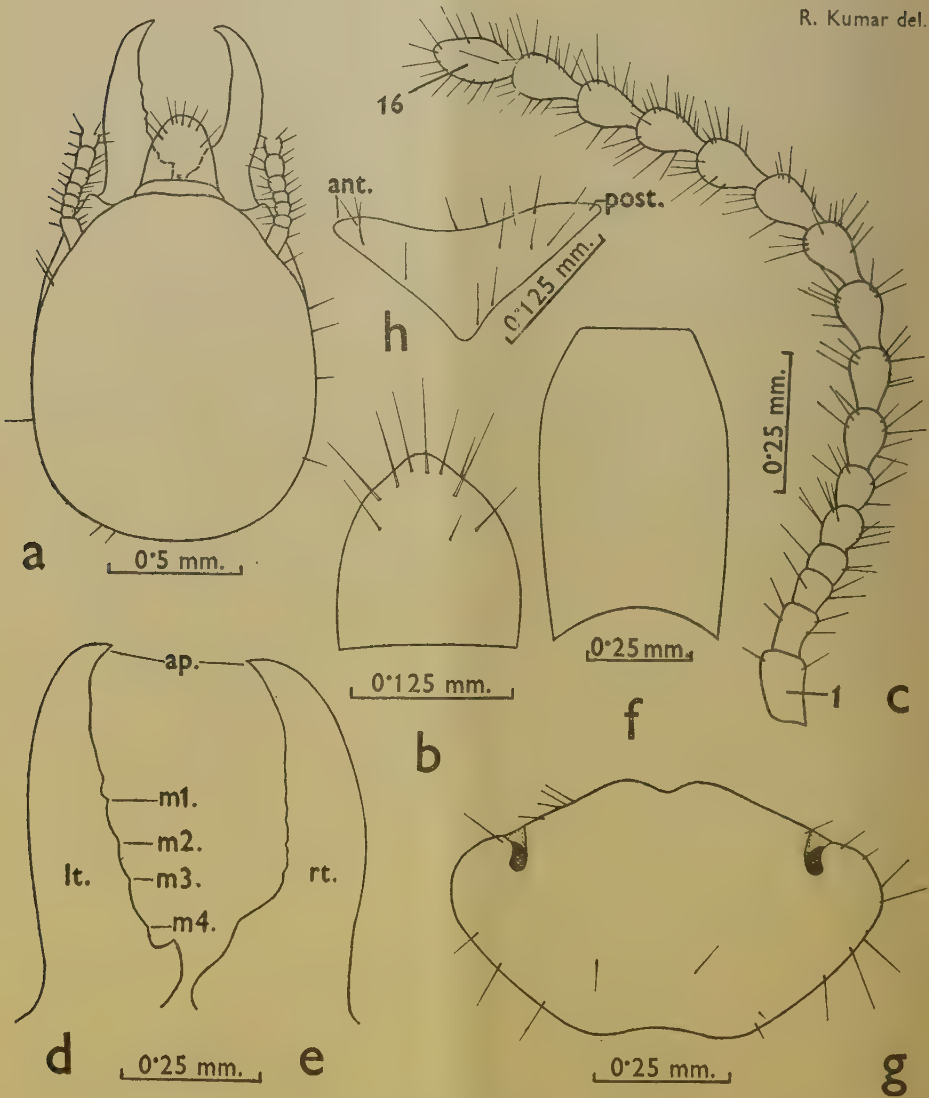
(*b*) Description (Text-figs. 5 and 6)

1. Imago—Unknown

2. Soldier (Text-fig. 5)

General : Head yellowish brown ; body, legs, and antennae light yellow ; mandibles dark brown at tip, yellowish brown at base. Head scarcely, and abdomen comparatively thickly pilose. Length of body including mandibles, 4·38 mm.

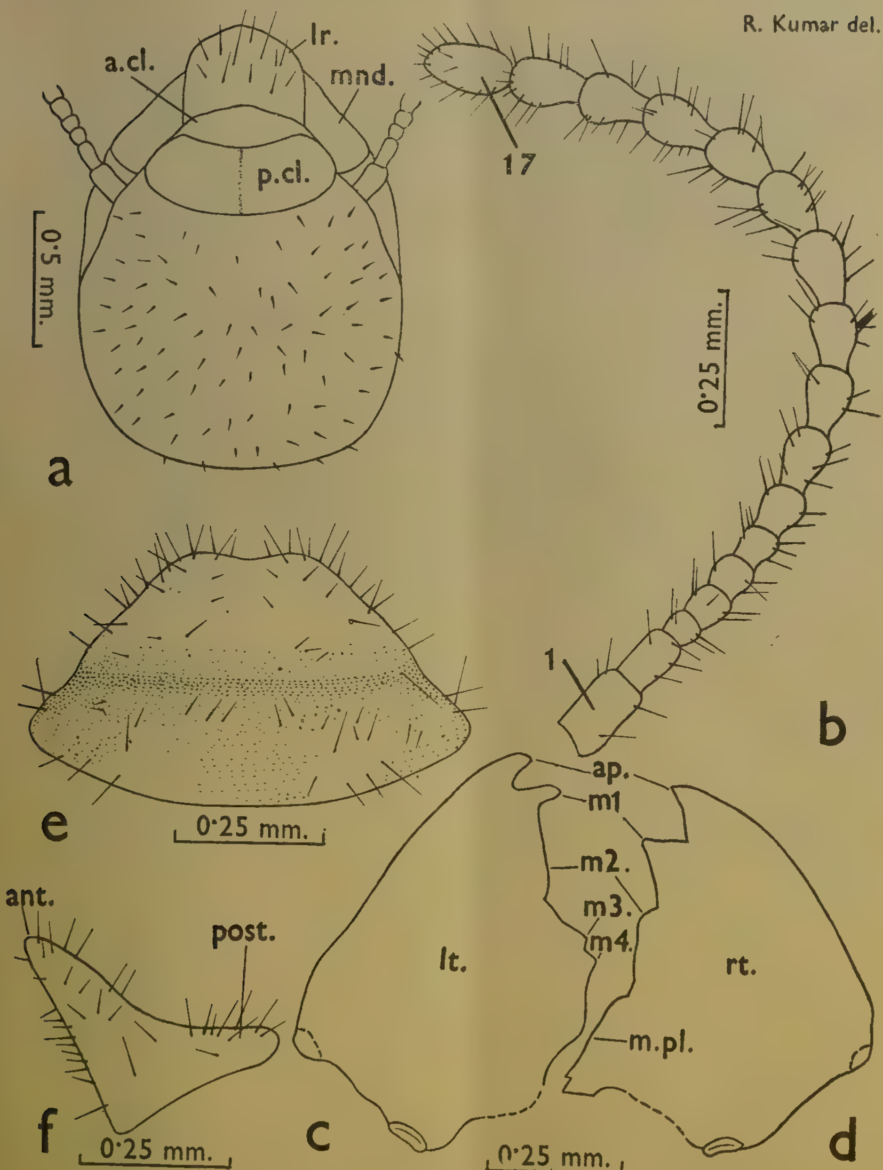
Head : Oval, about 1·5 times as long as wide widest in middle, gradually tapering anteriorly, also slightly narrowed behind ; swollen in side view due to the



TEXT-FIG. 5. *Hypotermes nongpriangi* Roonwal and Sen-Sarma (sp. nov.). Soldier.

(*a*) Head-capsule, in dorsal view. Only basal segments of antennae shown. (*b*) Labrum, in dorsal view. (*c*) Left antenna. (Slide No. 141). First and last segments numbered. (*d*) Left mandible, in dorsal view. (*e*) Right mandible, in dorsal view. (*f*) Post-mentum. (*g*) Pronotum, in dorsal view. (*h*) Pronotum, in side view (left).

ant., anterior; *ap.*, apical teeth of mandibles; *lt.*, left; *m1.—m4.*, 1st to 4th marginal teeth of mandibles; *post.*, posterior; *rt.*, right.



TEXT-FIG. 6. *Hypotermes nongpriangi* Roonwal and Sen-Sarma (sp. nov.). Worker.

(*a*) Head-capsule, in dorsal view. Only basal segments of antennae shown. (*b*) Antenna of right side. First and the last segments numbered. (*c*) Left mandible, in dorsal view. (Slide No. 138). (*d*) Right mandible, in dorsal view. (Slide No. 138). (*e*) Pronotum, in dorsal view. (Slide No. 138). (*f*) Pronotum, in side view (left).

acl., anteclypeus; *ant.*, anterior; *ap.*, apical teeth of mandibles; lr., labrum; *lt.*, left; *m1.—m4.*, 1st to 4th marginal teeth of mandibles; *mnd.*, mandible; *m.pl.*, molar plate of mandible; *pcl.*, postclypeus; *post.*, posterior; *rt.*, right.

bulging postmentum ; with but few bristles. *Fontanelle* : Not seen. *Antennae* : With 16 segments, all thickly pilose, with few long and many short bristles. Each of the distal segments (except last) club-headed ; proximal segments parallel sided. Segment-2 longer than 3, the latter slightly longer than segment-4, which is the smallest ; segments-5 and 6 subequal; segments-7-16 regularly increasing in length towards tip. *Eyes* : Absent. *Labrum* : Slightly broader than long, extending only about one-third the length of the mandibles ; tongue-shaped, bluntly pointed at the tip, with a few long bristles mostly near anterior margin. *Mandibles* : Dark smoky brown almost throughout ; elongated and slender, being about half the length of head, slightly curved inward at the tip, and pointed. Left mandible with 4 tooth-like serrations ; the first tooth near the middle ; first and second tooth very small, third and fourth relatively larger. Right mandible without teeth, but with minute serrations in basal half. *Postmentum* : Relatively wide ; length only *ca.* 1·5 times the maximum width ; narrow anteriorly, elsewhere with parallel sides ; relatively well arched ; not pilose.

Thorax : *Pronotum* : Weakly saddle-shaped, with few bristles ; anterior lobe relatively short, the margin distinctly incised in middle ; posterior margin rounded with a broad median concavity. *Legs* : Femora, tibiae and tarsi, all slender ; femora thinly and tibiae thickly bristled.

Abdomen : Fairly heavily pilose, with 10 visible terga ; cerci 2-jointed, terminal joint elongated.

Measurements. See Table III.

3. WORKER (Text-fig. 6)

General : Head straw-coloured, body whitish.

Head : Squarish, nearly as broad as long up to the side-base of mandibles ; sides parallel with round postero-lateral corners ; Y-suture not visible ; rather densely pilose with short hairs. *Fontanelle* : Not seen. *Eyes* and *ocelli* : Absent. *Antennae* : With 17 segments ; segment-3 shortest; segments-4 and 5 subequal. Postclypeus greatly swollen, a dark longitudinal line medially dividing it into two equal halves ; anteclypeus nearly rectangular, flat and whitish. *Labrum* : Longer than breadth, a little arched from side to side ; anterior margin round ; sides parallel ; with a few long and short bristles at tip. *Mandibles* : Strongly built ; deep yellow, except the inner margins which are dark brown. Left mandible with one apical and 4 marginal teeth ; first marginal finger-like and laterally projecting a little beyond the level of the apical ; second marginal very low ; third and fourth marginals posteriorly placed and subequal. Right mandible with one apical, 2 marginals and one molar plate ; first marginal subequal to apical, its posterior margin much elongated ; second marginal low ; posterior end of molar plate unequally bifurcated.

Thorax : *Pronotum* : Saddle-shaped ; much narrower than width of head ; anterior lobe relatively long, anterior border prominently concave in the middle ; posterior border somewhat straight. *Mesonotum* : Narrower than pronotum. *Metanotum* : Subequal to pronotum.

Measurements (in mm.)

1. Total length of body	3·90—4·08
2. Length of head to lateral base of mandibles	1·20—1·26
3. Maximum width of head	1·26—1·32
4. Maximum height of head	0·60—0·66
5. Length of labrum	0·42—0·48
6. Maximum width of labrum	0·60—0·60
7. Length of pronotum	0·48—0·48
8. Maximum width of pronotum	0·60—0·66

(c) Type-specimens

All material from a single source (see above).

Holotype : (i) One holotype soldier, with both antennae broken, in spirit, deposited with Zoological Survey of India, Calcutta. (ii) The broken antenna of the left side mounted on Slide No. 141 of F. R. I. and deposited as above. Broken parts of right antenna missing. (iii) One morphotype worker in spirit, deposited as above.

Paramorphotypes : (i) One paramorphotype worker, in spirit, deposited with the Zoological Survey of India, Calcutta. (ii) Two paramorphotype workers in spirit, (Regd. No. 19867) and one paramorphotype worker, dissected and mounted on Slide No. 138, deposited in the Entomological Collection, Forest Research Institute, Dehra Dun.

(d) Type-locality

Zoological Survey of India collecting Station No. 14., on bank of the river Nong-priang, Khasi Hills, *ca.* 1200 ft. above sea-level, North-East Frontier Agency (Assam).

(e) Type-host

Bark of a dead tree of an unknown species.

(f) Geographical Distribution

Known only from the type-locality.

(g) Comparisons

Hypotermes nongpriangi Roonwal & Sen-Sarma is easily distinguishable from *H. obscuriceps* (Wasm.), *H. xenotermitis* (Wasm.) and *H. winifredi* Ahmed by its long and slender mandibles and by its smaller size. It is closest to *H. sumatrensis* (Holmg.), but differs from the latter in the following characters : Somewhat larger in size ; labrum shorter, covering only one-third the length of mandibles (longer in *sumatrensis*, where it covers nearly half the length of mandibles) ; postmentum less arched (greatly swollen in *sumatrensis*).

TABLE III

Hypotermes nongpriangi *Roonwal and Sen-Sarma (sp. nov).*
body-measurements (in mm.) and indices of soldiers

Body-parts	Holotype (soldier)
I. GENERAL	
1. Length of body	4·38
II. HEAD	
2. Length of head to lateral base of mandible	1·32
3. Max. width of head	0·90
4. Max. height of head	0·84
5. Head Index I. (Width/Length)	0·68
6. Head Index II. (Height/Length)	0·64
7. Head Index III. (Height/Width)	0·93
8. Length of right mandible	0·66
9. Length of left mandible	0·66
10. Head-mandibular Index (Mandible-length/Head-length)	0·50
11. Length of labrum (excluding terminal bristles)	0·24
12. Max. width of labrum	0·30
13. Labrum Index (Width/Length)	1·25
14. Length of postmentum	0·66
15. Max. width of postmentum	0·42
16. Min. width of postmentum	0·30
17. Postmentum Index I (Max. width/Length)	0·64
18. Postmentum Index II (Min. width/Length)	0·45
19. Postmentum Index III (Min. width/Max. width)	0·71
III. THORAX	
20. Length of pronotum	0·54
21. Max. width of pronotum	0·78
22. Pronotum Index (Length/Width)	0·70

15. *Microtermes anandi* Holmgren (Syn. *Microtermes obesi* Holmgren)

(*a*) MATERIAL

Tube No. 24. A few soldiers and several workers. "Barkuda Island, Chilka Lake, Ganjam District, Madras Presidency" (now in Orissa State). 14-iv-1922.

Tube No. 46. 2 soldiers and a few workers. As above.

Tube No. 28. A few soldiers, workers, imago-nymphs and eggs. Locality as in Tube 24. Coll. *N. Annandale*, 17-ii-1923. "From nest No. 25."

(*b*) MEASUREMENTS (in mm.)

A few soldiers measured as follows, the number of specimens measured being indicated within square brackets.

———	Tube No. 24	Tube No. 46	Tube No. 28
1. Total length of body	3·18—3·30 [4]	3·12—3·18 [2]	3·18—3·48 [4]
2. Length of head with mandibles	1·26—1·32 [4]	1·32—1·32 [2]	1·32—1·38 [4]
3. Length of head to base of mandibles	0·90—0·90 [4]	0·78—0·84 [2]	0·84—0·90 [4]
4. Max. width of head	0·66—0·72 [4]	0·72—0·72 [2]	0·72—0·78 [4]
5. Length of pronotum	0·24—0·30 [4]	0·30—0·30 [2]	0·30—0·30 [4]
6. Max. width of pronotum	0·42—0·42 [4]	0·48—0·48 [2]	0·48—0·60 [4]

(*c*) REMARKS

Microtermes anandi Holmgren (21 April, 1913, *J. Bombay nat. Hist. Soc.*, Bombay, 22(1), p. 114) has priority over *M. obesi* Holmgren (23 May, 1913, *Kungl. Svenska Vet. Akad. Handl.*, Stockholm, 50(2), p. 150), the latter being a synonym. T. B. Fletcher (in Holmgren & Holmgren, *Mem. Dept. Agr. India*, Calcutta, 5(3) 1917, p. 160 foot-note) and Snyder, *Smiths. Misc. Coll.*, Washington, 112, 1949 p. 252, however, give priority to *obesi*, without assigning reasons.

The specimens from Barkuda Island referred to by Silvestri (1923, *Rec. Indian Mus.*, Calcutta, 25 (2), p. 225,) are probably from the same lot as above.

Subfamily (iv). Nasutitermitinae*

16. *Nasutitermes matangensis matangensiformis* (Holmgren).

(*a*) MATERIAL

Tube No. 96.—Eight soldiers (one damaged) and one nymph of imago. "Camorta Island," in the Nicobar Island group, Indian Ocean. The label above states "Nest building ants."

* The total body-length of the soldiers of Nasutitermitinae is measured by adding the length of head with rostrum and the length of remaining body-parts. As the head is prolonged posteriorly behind the neck, this value will be a little more than the value obtained by the straight line distance between the foremost and the hindmost tips of the body.

(b) Measurements (in mm.)

Four soldiers measured as follows:

1. Total length of body	4·44—4·88
2. Length of head with rostrum	1·86—1·92
3. Length of head without rostrum	1·14—1·20
4. Maximum width of head	1·20—1·26
5. Length of pronotum	0·24—0·30
6. Maximum width of pronotum	0·60—0·66

(c) Remarks

Examination of a series of specimens belonging to soldier caste (including cotype specimens) of the following species and forms, has shown that they can be regarded as forms or subspecies of *Nasutitermes matangensis* (Haviland):

N. matangensis (Haviland)

N. matangensis matangensioides (Holmgren)

N. matangensis pyricephalus (Kemner)

N. matangensiformis (Holmgren)

N. matangensiformis obscurus (Holmgren) (Specimens not seen)

It is possible that some other allied species might also fall in line within the group. There are three points to consider in this connection:

(i) The relative size of head and body. This is a very variable character even within the same subspecies, and although certain tendencies are noticeable, much emphasis need not be placed on this character.

(ii) The relative sizes of the 2nd and 3rd antennal segments. In *matangensis matangensis* the 3rd segment is said to be about twice the length of the 2nd, while in *N. m. matangensiformis* it is said to be equal or subequal. This distinction is not reliable and sometimes the proportions vary in the right and left antenna of the same specimen. Furthermore, it was often seen, especially in the "*matangensis*" lot that the 3rd segment is sometimes clearly "divided" into two (3rd and 4th) and the 3rd segment proper is less than subequal to or even slightly smaller than the 2nd ; in this case the antenna is 14-segmented. In other *matangensis* specimens, this division is either incomplete or absent, in which case the antenna is 13-segmented and the 3rd segment is longer (about twice) than the length of the 2nd.

(iii) The presence of a sparse row of long, prominent hairs on the tergites (excluding the first few) in the *matangensiformis* lot, and their virtual absence in typical *matangensis*. These two extremes are connected by intermediates, *e.g.*, in *m. pyricephalus* (a few hairs) and *m. matangesioides* (hairs more than in *m. pyricephalus* but less than in *matangensiformis*).

17. Hospitalitermes blairi Roonwal and Sen-Sarma (sp. nov.)

(Tables IV and V ; and Text-figs. 7, 8 and 9)

(*a*) MATERIAL

In spirit, in a single vial (No. 95), in the collection of Zoological Survey of India, Calcutta, with several soldiers and workers, coll. *H. S. Rao*, 15.xii 1934, from a "marching column of ants on the jungle path, south of creek near S. Corbyn's Cave, Port Blair", Andaman Islands.

(*b*) DESCRIPTION

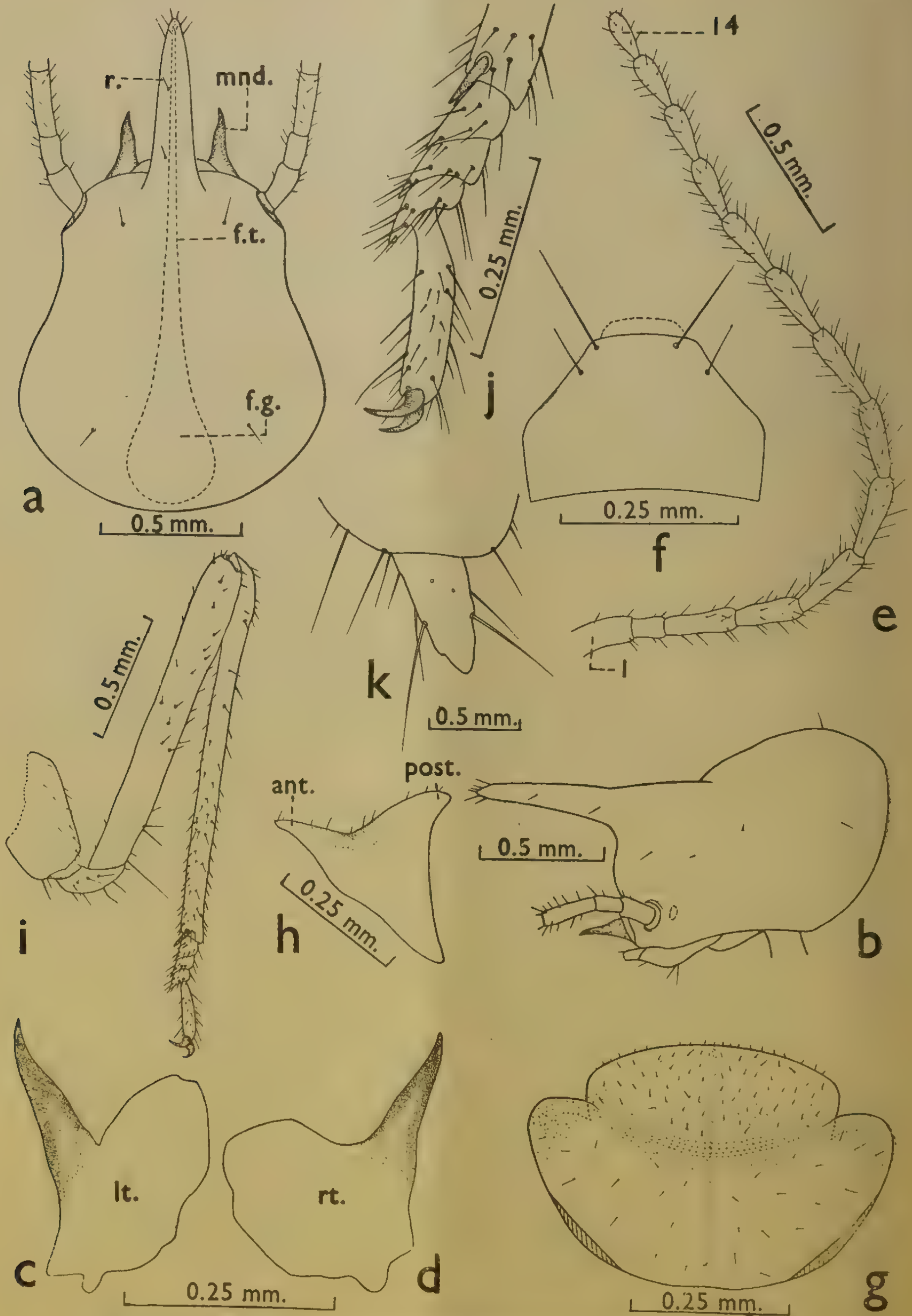
(Text-figs. 7, 8 and 9)

1. IMAGO—Unknown

2. SOLDIER (TEXT-FIG. 7)

General : Head-capsule brown, with reddish tinge behind frontal constriction ; much paler elsewhere. Antenna brown proximally, paller distally. Thoracic tergites, coxae and femora light brown. Abdominal tergites dark brown ; abdominal sternites, tibiae and tarsi brownish yellow. Pilosity very sparse. Approximate body-length (including rostrum) 4·0-4·5 mm.

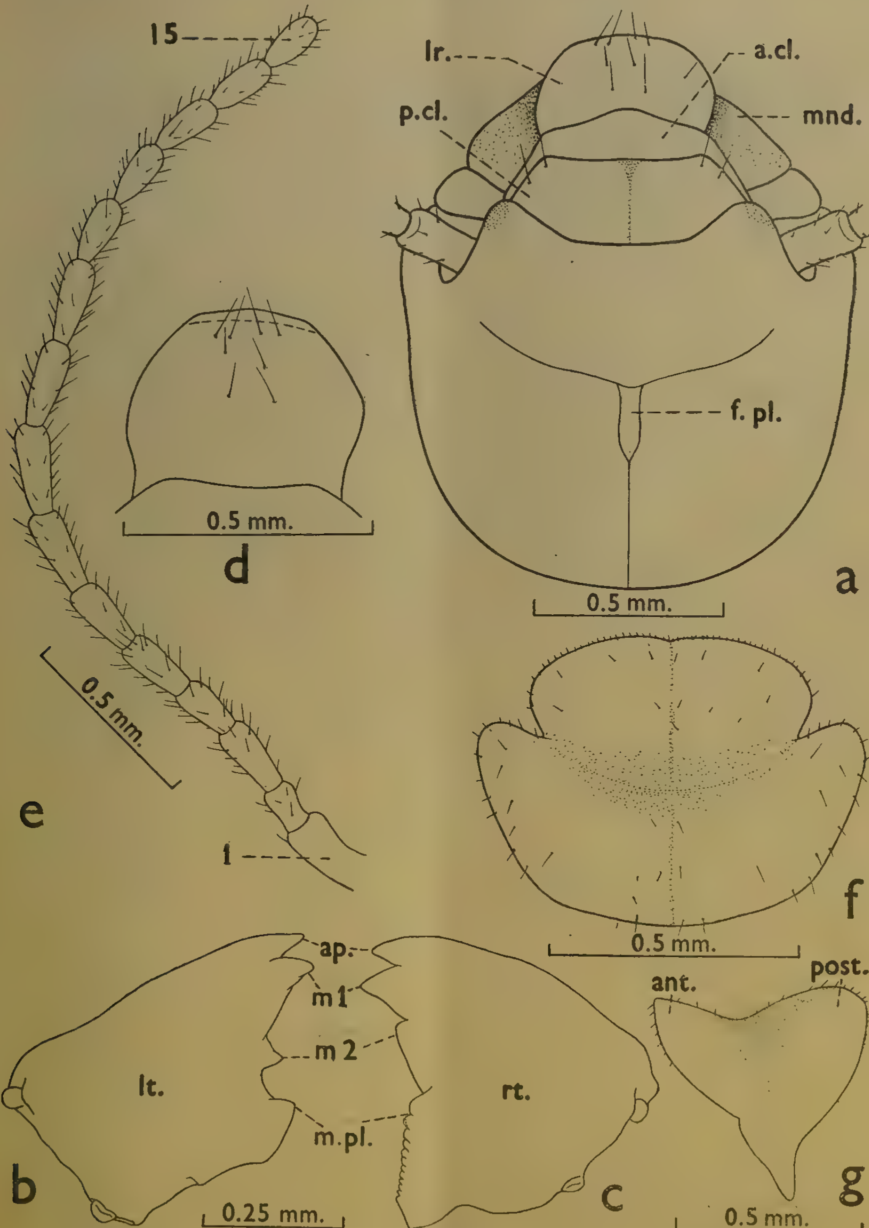
Head : Head-capsule pear-shaped from above with a constriction behind the base of antennae. Nearly as broad as long ; broadest posteriorly. Laterally, head posteriorly uplifted and with a marked posterior bulge ; dorsal profile with a strong depression in middle. With a pair of bristles on vertex, a pair behind the rostrum and a few on the rostrum. *Rostrum :* nearly cylindrical, slender ; a little shorter than head-capsule, laterally slightly uplifted ; rostal hump rudimentary or absent. With a few bristles at the tip. A pair of suboval, white spot present laterally behind antennal foveolae ; Fontanelle gland and fontanelle tube prominent. *Antennae :* very long, with elongated, slender segments. With 14 segments, all thickly pilose, with a few long and many short bristles ; segment 3 generally a little more than twice but never thrice the length of 2 ; segment 4 a little shorter than 3 ; segments 5-8 gradually increasing, and segments 9-14 gradually decreasing, in length, the last one the shortest. *Labrum :* small, rectangular, broader than long; anterior margin straight ; not pilose. *Mandibles :* Vestigeal ; each with a dark brown, elongated, pointed, spine-like tip ; without marginal tooth ; inner margin (molar surface) of each mandible semicircular. *Postmentum :* Very small ; broad posteriorly, narrow anteriorly, with sloping sides ; anterior margin nearly straight, posterior one slightly concave.



TEXT-FIG. 7. *Hospitalitermes blairi* Roonwal and Sen-Sarma (sp. nov.). Soldier.

(*a*) Head-capsule, in dorsal view. Only basal portion of antennae shown. (*b*) Head-capsule, in side view. (*c*) Left mandible, in dorsal view. (*d*) Right mandible, in dorsal view. (*e*) Antenna of right side. First and last segments numberd. (*f*) Postmentum, in dorsal view. (*g*) Pronotum, in dorsal view. Membranous areas line-shaded. (*h*) Pronotum, in side view (left). (*i*) Fore-leg (right). (*j*) Tarsus of fore-leg (enlarged). (*k*) Cercus (right).

ant., anterior ; *f.g.*, fontanelle gland ; *f.t.*, fontanelle tube ; *lt.*, left ; *mnd.*, mandible ; *post.*, posterior ; *r.*, rostrum ; *rt.*, right.



TEXT-FIG. 8. *Hospitalitermes blairi* Roonwal and Sen-Sarma (sp. nov.). Worker major.

(*a*) Head-capsule, in dorsal view. Only basal portion of antennae shown. (*b*) Left mandible, in dorsal view. (*c*) Right mandible, in dorsal view. (*d*) Labrum, in dorsal view. (*e*) Antenna (left). First and last segments numberd. (*f*) Pronotum, in dorsal view. (*g*) Pronotum, in side view (left).

a.cl., anteclypeus ; *ant.*, anterior ; *ap.*, apical teeth of mandibles ; *f.pl.*, fontanelle plate ; *lr.*, labrum ; *lt.*, left ; *m1.—m2.*, 1st and 2nd marginal teeth of mandibles ; *mnd.*, mandibles. *m.pl.*, molar plate of mandibles ; *p.cl.*, postclypeus ; *post.*, posterior ; *rt.*, right.

Thorax : Terga marked by a fine white median longitudinal line. *Pronotum :* saddle-shaped ; width a little more than half the head-width ; width slightly less than twice the length ; deeply incised antero-laterally ; anterior margin convex ; inner margin of anterior border with a row of small hairs ; posterior margin convex, not pilose. *Mesonotum* and *metanotum :* Not notched at the posterior margin ; sparsely pilose. *Legs :* Femora, tibiae and tarsi, all slender and much elongated ; hind-leg longest, hind-femur reaching beyond the tip of abdomen, hind-tibia nearly 1·5 times longer than hind-femur. Tarsi 4-segmented ; segments 1-3 small and subequal ; segment—4 longest (nearly as long as the remaining three put together) and moderately pilose ; distally bearing two dark, curved claws.

Abdomen : With 10 terga and 9 sterna ; terga dark brown, sterna brownish yellow. Last 3 terga weakly pilose, the remaining without hairs. Sterna densely pilose. Cerci with a broad basal and an elongated terminal segment ; with few bristles.

Measurements—See Table IV.

3. Worker Major (Text-fig. 8)

General : Head-capsule and femora brown ; abdominal tergites and postclypeus dark brown ; antenna and pronotum paler ; tibiae, tarsi and abdominal sternites straw-coloured. Sparsely pilose dorsally and densely pilose ventrally.

Head : Squarish, nearly as broad as long (up to base of mandibles) ; sparsely pilose dorsally at the anterior end. Y-suture prominent. Fontanelle covered with a white, translucent, shinning, suboval or longish plate situated medially at the junction of two frontal sutures. Antenna : 15-segmented, all densely pilose ; segment—3 much longer than 2 and 4 (*cf.* worker-minor) ; segment—5-10 gradually increasing and segment—11-15 gradually decreasing in length, the last one being shortest. Postclypeus : Swollen, dark-brown ; width about twice the length. Anteclypeus well marked. Labrum broader than long, with a few long hairs.

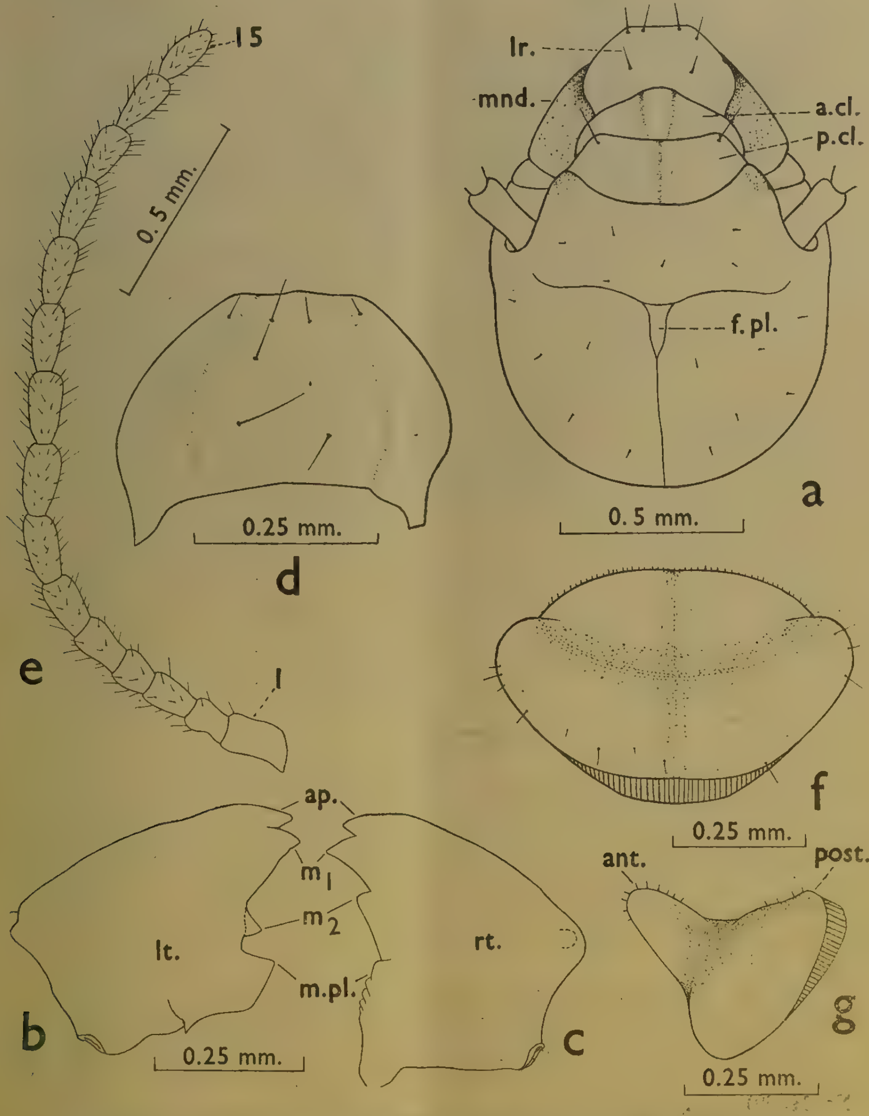
Mandibles : Stout ; light brown, inner margin darker. Left mandible with one apical and 2 marginal teeth ; apical tooth well developed and slightly shorter than 1st marginal ; 2nd marginal triangular, short and well developed ; widely separated from the 1st. Right mandible with one apical and 2 marginal teeth and with a molar plate ; 1st marginal triangular, 2nd marginal short and low, molar plate with undulating distal margin.

Thorax : Pronotum : Strongly saddle-shaped ; width more than half the head-width ; deeply incised antero-laterally (*cf.* worker minor) ; anterior margin a little convex ; not notched medially ; posterior margin strongly concave. Legs : long and slender ; hind-femur reaching beyond tip of abdomen.

Abdomen : With 10 terga and 9 sterna ; terga not pilose excepting the last 2 or 3 which are sparsely pilose ; sterna densely pilose.

4. Worker Minor (Text-fig. 9)

General : A little smaller than worker major.



TEXT-FIG. 9. *Hospitalitermes blairi* Roonwal and Sen-Sarma (sp. nov.) Worker minor.

(*a*) Head-capsule, in dorsal view. Only basal portion of antennae shown. (*b*) Left mandible, in dorsal view. (*c*) Right mandible, in dorsal view. (*d*) Labrum, in dorsal view. (*e*) Antenna (left). First and last segments numbered (*f*) Pronotum in dorsal view. Membraneous areas line-shaded; (*g*) Pronotum, in side view (left). Membraneous areas line-shaded.

a.cl., anteclypeus ; *ant.*, anterior ; *ap.*, apical teeth of mandibles ; *f. pl.*, fontanelle plate ; *lr.*, labrum; *lt.*, left ; *m1.—m2.*, 1st and 2nd marginal teeth of mandibles ; *mnd.*, mandible ; *m.pl.*, molar plate of mandibles ; *p.cl.*, postclypeus ; *post.*, posterior., *rt.*, right.

Head : Squarish, a little broader than long or nearly as broad as long. Y—suture prominent. Frontanelle as in the worker major. Antennae : densely pilose ; basal segments shorter, distal segments elongated ; 15-segmented ; segment—3 a little longer than 2 and 4 (*cf.* worker major) ; segment—4 subequal to 2 ; remaining ones nearly subequal. Postclypeus swollen, darkly pigmented ; length more than half the width. Anteclypeus well developed. Labrum rectangular ; with anterior margin convex. Mandibles as in worker major.

Thorax : Pronotum without antero-lateral incision, otherwise as in worker major.

Abdomen : As in worker major.

Measurements (in mm.) of workers—

——	*Workers major*	*Workers minor*
1. Total body-length	3·96—4·26	3·72—3·96
2. Length of head to lateral base of mandibles	1·02—1·02	0·90— ·96
3. Max. width of head	1·14—1·14	1·02—1·02
4. Max. height of head	0·54—0·60	0·48—0·54
5. Length of labrum	0·18—0·24	0·24—0·24
6. Max. width of labrum	0·30—0·30	0·30—0·30
7. Length of pronotum	0·54—0·54	0·30—0·42
8. Max. width of pronotum	0·72—0·72	0·60—0·66

(c) Type-Specimens

All specimens from a single source (see above under Material).

(*i*) *Holotype* and *morphotypes* : One holotype soldier, one morphotype worker major and one morphotype worker minor, in spirit, in a single vial (No. 95 of Z.S.I.), deposited with the Zoological Survey of India, Calcutta. For measurement of holotype soldier, see Table IV.

(*ii*) *Paratypes* and *paramorphotypes*, from the type colony : Deposited with the following :

(*a*) Zoological Survey of India, Calcutta ; thus : One paratype soldier and two paramorphotype workers (one major and one minor), in spirit, in a single vial.

(*b*) Forest Research Institute, Dehra Dun : One paratype soldier and two paramorphotype workers (one major and one minor), in spirit, in a single vial (Regd. No. 19869).

(*c*) Prof. Alfred E. Emerson, Chicago University, Chicago, U.S.A. : One paratype soldier and two paramorphotype workers (one major and one minor), in spirit, in a single vial.

TABLE IV

Hospitalitermes blairi *Roonwal and Sen-Sarma (sp. nov.): Body-measurements (in mm.) and indices of soldiers.*

Body-parts	Number of specimens measured	Range	Holotype (Soldier)
I—GENERAL			
1. Length of body (head+remaining part of body)	7	3·90—4·44	4·44
II—HEAD			
2. Length of head with rostrum	7	1·42—1·74	1·74
3. Length of head without rostrum	7	1·02—1·14	1·14
4. Length of rostrum	7	0·60—0·66	0·60
5. Max. width of rostrum	7	0·12—0·13	0·13
6. Max. width of head	7	0·96—1·08	1·08
7. Min. width of head	7	0·66—0·72	0·72
8. Posterior bulge of head	7	0·36—0·54	0·42
9. Max. height of head	7	0·66—0·78	0·78
10. Min. height of head	7	0·54—0·60	0·60
11. Rostrum-Head Index I (Rostrum-length/Head-length without rostrum)	7	0·53—0·68	0·53
12. Rostrum-Head Index II (Max. rostrum-width/Max. head-width)	7	0·12—0·13	0·12
13. Head Bulge Index (Posterior head-bulge/Head-length without rostrum)	7	0·32—0·48	0·37
14. Head contraction Index (Min. head-width/Max. head-width)	7	0·66—0·70	0·66
15. Head Index I (Max. width/Length without rostrum)	7	0·84—1·16	0·95
16. Head Index II (Max. height/Length without rostrum)	7	0·63—0·82	0·68
17. Head Index III (Max. height/Max. width)	7	0·61—0·75	0·72
18. Antennal segments: Length of segment—3/Length of segment—2.	7	2·25—2·50	2·50
III—THORAX			
19. Length of pronotum	7	0·36—0·36	0·36
20. Max. width of pronotum	7	0·54—0·60	0·60
21. Pronotum Index (Length/Max. width)	7	0·60—0·67	0·60
22. Length of hind femur	7	1·80—1·86	1·80
23. Max. width of hind femur	7	0·18—0·18	0·18
24. Length of hind tibia	7	2·46—2·40	2·40

TABLE V

Comparative indices of soldiers of three species of Hospitalitermes

Indices	*blairi* R. & S. (sp. nov.) [7]	*schmidti* Ahm. [4]	*rufus* (Hav,) [1]
1. Rostrum-Head Index I (Rostrum-length/Head length without rostrum)	0·53—0·68	0·48—0·50	0·42
2. Rostrum-Head Index II (Max. rostrum-width/ Max. head-width)	0·12—0·13	0·15—0·16	0·14
3. Head contraction Index (Min. head-width/Max. head-width)	0·66—0·70	0·55—0·63	0·66
4. Antennal segments: Length of segment—3/ Length of segment—2.	2·25—2·50 (mostly 2·50)	1·80—2·25 (rarely 2·25)	1·60

Note. Number of specimens measured is indicated in square brackets.

(*d*) TYPE-LOCALITY

From "a jungle path, south of creek near " S. Corbyn's Cave ", Port Blair, Andaman Islands, Indian Ocean.

(*e*) TYPE-HOST

Unknown.

(*f*) GEOGRAPHICAL DISTRIBUTION

Known only from the type locality.

(*g*) COMPARISONS (Tables IV and V)

The new species, *H. blairi* R. and S., is close to *H. schmidti* Ahmad and *H. rufus* (Hav.), but differs in the following respects :

Soldiers : The 3rd segment of the antenna is *over* twice as long (2·25-2·50 times) as the length of the 2nd in *blairi*, about twice (1·80-2·25 times) in *schmidti* and less than twice (1·60 times) in *rufus*. The head in *blairi* is pale reddish brown without a smoky tinge ; in the other two species deeper reddish brown with a distinctly smoky tinge on the dorsum. The rostrum is longer and thinner in *blairi*, shorter and thicker in the other two. The head profile is more concave on the dorsum in *blairi*, less so in the other two. The head indices differ as shown in Table V.

Workers : The workers major differ as follows : Head and body pale brown without smoky tinge in *blairi*, darker and with a smoky tinge in the other two. Fontanelle plate is well marked in *blairi* and *rufus*, but appears to be much less conspicuous in *schmidti*. The apical tooth of left mandible equals the 1st marginal in *blairi* and is somewhat smaller in *rufus* and *schmidti*. The 3rd antennal segment is much longer than the 2nd in *blairi*, only a little longer in *rufus* and *schmidti*.

18. *Trinervitermes biformis* (Wasmann).

(*a*) Material

*Tube No. 63a**. A few soldiers (major and minor). "Sarai (land), 2,700 ft. Rewa State" (now in Vindhya Pradesh), Z.S.I. Coll. Sta. No. 31, *H. S. Pruthi* coll. (Nerbudda Survey), February, 1927.

Tube No. 62. Workers only (as above)

(*b*) Measurements (in mm.)

Four major and four minor soldiers measured as follows:

	Soldiers major	*Soldiers minor*
1. Total length of body	4·92—5·40	3·78—4·08
2. Length of head with rostrum	2·40—2·46	1·68—1·80
3. Length of head without rostrum	1·50—1·50	0·96—1·08
4. Max. width of head	1·44—1·50	0·72—0·72
5. Length of pronotum	0·24—0·30	0·18—0·24
6. Max. width of pronotum	0·60—0·72	0·36—0·48

19. *Trinervitermes heimi* (Wasmann).

(*a*) Material

Tube No. 61. Three soldiers (major) and four workers (major). Hill near Koilari, 2,700 ft., Rewa State, (now in Vindhya Pradesh), Z.S.I. Coll. Sta. 37. *H. S. Pruthi* coll. (Nerbudda Survey), February, 1927.

(*b*) Measurements (in mm.)

Three soldiers (major) measured as follows:

1. Total length of body	5·28—5·52
2. Length of head with rostrum	2·40—2·40
3. Length of head without rostrum	1·50—1·56
4. Max. width of head	1·44—1·50
5. Length of pronotum	0·24—0·30
6. Max. width of pronotum	0·72—0·78

* This tube bears the original number 63 which appears to be an error, since there is another tube in Z.S.I. lot numbered 63 and which contains *Coptotermes travians* (Havi.) (see under that species).

EFFECT OF CHEMICAL HORMONES ON THE CARBOHYDRATE AND NITROGEN CONTENTS OF COTTON PLANT

By R. H. DASTUR and JAYENDRA BHATT, Institute of Plant Industry, Indore

(Received for publication on March 25, 1955)

(With 27 text-figures)

THE detailed study of carbohydrate contents of the different parts of cotton plant was first made by Mason and Maskell [1928-1930] in Trinidad, B. W. I. Their main object was to study the transport of carbohydrates within the plant body, the form in which they were transported, and the channels in the plant body through which transport took place. They considered that sucrose was the main carbohydrate which was transported and the sieve tubes of the bark were the main paths of conduction.

Caskey and Gallup [1931] were the next to study the changes in the sugar content of cotton bolls during their development from 21-day stage after setting upto 59 days when the bolls were fully open, but the first attempts to study the periodic changes in the concentrations of carbohydrate fractions of the cotton plant were made by Ergle [1936], who found a fall in the total sugars from the seedling stage to square formation stage with a very sharp increase during the bolling stage. These studies were again continued by Ergle, Hessler and Adams [1938] and they also confirmed Ergle's previous finding of a decrease in concentration at the square formation stage and a sharp rise at the fruiting stage.

A further contribution to our knowledge of carbohydrate concentrations in the cotton plant was made indirectly by Eaton and Joham [1944] in their efforts to determine the causes for a decline in the mineral uptake by cotton plants when they reached the bolling stage. They concluded from their results that a reduced movement of carbohydrates to the roots at that stage was causing a decline in the mineral uptake as sugars supplied the respiratory material from which energy was derived for utilisation in the mineral uptake. The reduced movement of sugars to the roots was a result of the flow of carbohydrates to the developing bolls.

It had long been believed that carbohydrate supply was a main factor that limited the boll formation. The bolls retained and matured by the plant was a function of the number it can nourish. In order to test this finding Eaton and Rigler [1945] undertook to study the effect of nitrogen and light intensity and fruiting on carbohydrate utilisation in the cotton plant. They found that carbohydrate concentration was 2·7 times higher under high light intensity (10,000 f.c.) than under low light intensity (1,000 f.c.). Low light intensity was also found to limit the vegetative growth and fruiting and it can, therefore, be concluded that carbohydrate supply in the low light was the limiting factor. But these conclusions were not supported by their results obtained with high light intensity. Though the high

light plants set twice as many bolls per 100 gm. of fresh weight, the carbohydrate concentrations in the leaves and root bark were not reduced to the same level as those found in low light. The question was whether high light intensity alone was responsible for better fruitfulness.

Eaton and Rigler [1945] thought the cause for greater fruitfulness under high light intensity was either on the formation of or inhibition by some hormone which would determine the kind of activity, vegetative or reproductive, that would predominate or on enzyme production that would help in carbohydrate utilisation. Thus the question of the relation between fruitfulness and carbohydrate utilisation remained undetermined.

It is recently found by Ergle and Eaton [1951] that sulphur played an important role in carbohydrate metabolism of the plant. A sulphur deficiency was found to be associated with a total absence of reducing sugars and sucrose in the leaves. The same was found to be the case with starch even though to a lesser extent.

It is clear from the above short review of the work done on the carbohydrate concentrations in the cotton plant from different standpoints that the cotton plant at maturity contains certain amount of surplus carbohydrates stored up especially in the roots and stems. These amounts varied according to the conditions of their growth. There was also a tendency of accumulation of carbohydrates under low or high nitrogen supply [Eaton and Rigler, 1945] and under conditions of drought [Eaton and Ergle, 1948]. There appears to be no relation between fruitfulness and carbohydrate supply as larger number of bolls are found to be produced by those plants which contain larger quantities of carbohydrate at the end of their fruiting activity.

The carbohydrate accumulation in the cotton plant represents the difference between the input, i.e. amount produced by photosynthesis and their utilisation in the vegetative and reproductive growth. It is possible that the enzymatic activities may be associated with such accumulations as the continuous formation, of different enzymes was necessary for the normal growth of plants. If by some means enzyme formation can be prolonged it may result in greater utilisation of carbohydrates in setting and development of a greater number of bolls.

The cotton plant in the Malwa plateau grows under rather unfavourable seasonal conditions as this cotton tract is mainly rainfed. The cotton is sown at the break of the south-west monsoon in the third week of June when the temperatures drop, the hours of sunshine decrease and soil becomes waterlogged during the months of July and August. These conditions are far from ideal from the point of view of vegetative growth. Cloudy weather and lower temperatures must be acting as a deterrent for the photosynthetic activity of the plant and production of carbohydrates in the leaves must be greatly reduced. During this period it is observed that plant growth was greatly retarded. They begin to grow from the month of September when the bright weather gradually sets in and the temperature rises. The month of October was the period of maximum vegetative activity and it is also the time when the reproductive growth also occurred. During these months

a marked rise in the photosynthetic activity was expected to occur to meet the requirements of increased vegetative growth and of the developing bolls.

The vegetative structure produced by the cotton plant growing in the Malwa tract was small when the cotton was sown with rains. Its average height was 18 to 24 inches per plant and its dry weight fluctuated between 15 to 25 gm. The average number of bolls produced per plant varied from two to four. This was very small as compared with plants growing under irrigated conditions. This was also small in comparison with plants growing in Gujarat and other rainfed tracts. It would be, therefore, interesting to study the carbohydrate metabolism of the cotton plant to determine how far carbohydrate production under conditions of cloudy weather and low temperature limited the vegetative and reproductive growth, and whether at the end of the bolling season there was any surplus of carbohydrates stored up in the leaves and stems as was found by the previous workers.

It is possible that nitrogen may be acting as a limiting factor thus upsetting the carbohydrate nitrogen balance which would result in the maturation of a smaller number of bolls with certain amounts of carbohydrates remaining unutilised. This point, therefore, required to be investigated by determining the nitrogen contents of the different parts of the plant.

The growth regulating substances within the plant body may be playing some part in the development of the bolls and non-utilisation of carbohydrates through their effect on the production of auxins which in turn would effect the enzymatic activities. There is enough literature on the effect of chemical hormones on the carbohydrate and nitrogen metabolism in plants. Stuart [1938] studied the effect of 0·01 per cent solution of indoleacetic acid on kidney bean cuttings and he found an accumulation of carbohydrates and nitrogen in the cut ends which were in the solution for four hours. This substance appeared to mobilise the food substances which, therefore, promote the rapid growth of roots, thus explaining the finding of Zimmerman and Willcoxan [1935] that the rate of root initiation increased when chemical hormones were applied. Mitchell and Stuart [1938-39] have further shown that when α-indoleacetic acid was applied to bean cuttings there was an accumulation of sugars. It also increased the weight of hypocotyl and of the roots. It appeared from their results that treatment with this chemical hormone increased the proteolytic enzymatic activities of the cuttings and later on the accumulated nitrogen was transferred to other portions. Wost [1949] also found a temporary increase in the total available carbohydrates in the stems of Buck wheat when treated with 2-4-Dichlorophenoxyacetic acid.

Greaulack and Sucha Singh [1949] studied the effects of applications of napthalene acetic acid and napthalene acetamide on the development of the cotton plant and they have found an increase in the setting percentage of bolls by the use of these chemical hormones. Another interesting finding was the conclusion drawn from the numbers of leaves on the treated plants and the control plants that the former had a higher rate of photosynthesis per unit area.

When sensitive plants are treated with chemical hormones especially 2-4-D a reduction in carbohydrates and accumulation of nitrogen have been usually noted as found by Siely and Klapes [1948] in the case of wheat, by Mitchell and Brown [1945] in the case of Morning Glory, Resmussen [1948] in the case of Dandelion and Luecke, Taylor and Hamner [1949] in the case of Red Kidney bean.

Brown, Holdman and Hogwood [1948] reported injuries to the cotton plant by the use of 2-4-D when used as weed killers and similar observations were recorded by Dunlap [1948] and Staten [1948]. Rakitin, Ovecherov and Nigkovaskoza [1948] found a reduction in boll shedding but this fact could not be confirmed by Eaton [1949] though Greulack and Sucha Singh [1949] found a reduction in boll shedding through the use of napthalene acetic acid as stated above.

McIllarth [1950] studied the effect of application of maleic hydrazide in the form of diethanolamine salt on the growth of cotton plant in the form of spray and he found that the growth of the plant was inhibited owing to the collapse of the phloem cells which probably interfered with the translocation of carbohydrates. The leaf blades of treated plants, therefore, contained more carbohydrates than the leaf blades of the control plants.

Ergle and Dunlap [1949] have investigated in great details the effect of 2-4-D on the growth and chemical composition of the cotton plant using pot technique. They did not find any appreciable change in the concentration of carbohydrates or nitrogen except in the case of the largest dose where a decrease in starch content was noticed.

The evidence regarding the effect of chemical hormones on the carbohydrate or nitrogen accumulation in plants reviewed above is rather conflicting though more recent work has not supported such accumulation. The main work has been done with the use of 2-4-D which is now extensively used as a weed killer.

Recently the effect of four chemical hormones, viz. 2-4-dichlorophenoxyacetic acid, 2-3-5-triiodobenzoic acid, α-Napthalene acetic acid and α-3 indolyl butyric acid on the morphological characters of the cotton plant (Indore-1 and Malwi-9) has been investigated in the Scheme for Cotton Physiological Research by Dastur and Ved Prakash [1954]. They have used solutions of these substances as spray as well as applied to the soil. The effect on morphological characters was more pronounced when used as a spray than when applied to the soil. The effects were similar on both American upland cotton, Indore-1 and the *desi* cotton Malwi-9, though there were differences of degree. 2-4-D produced all deleterious effects while the other three hormones showed two common beneficial effects:

(1) An increase in setting percentage thus giving rise to a larger number of bolls than the untreated plants, and

(2) an increase in the yield of seed cotton per plant.

It was, therefore, clear that all hormones did not have the same effects on the growth of the cotton plant. Some like 2-4-D were positively injurious while other had beneficial effects like setting of a larger number of bolls. It is not known what changes in the carbohydrate and nitrogen metabolism of the cotton plant the three

hormones 2-3-5-triiodobenzoic acid, α-napthalene acetic acid and α-3 indolyl butyric acid produced. Maturation of a greater number of bolls by their applications may mean either more effective utilisation of the carbohydrate or an increase in the enzymatic activities through the production of auxins or a higher rate of photosynthetic activity. More effective utilisation of carbohydrates can be revealed by the carbohydrate analysis of the plants grown under identical conditions except for the applications of the hormones. If the treated plants get more depleted of their carbohydrates at the maturation stage than the control plant, it may mean a greater utilisation of carbohydrates. The analysis of the plants before the maturation stage for carbohydrates may reveal whether the rate of photosynthesis was the same both in the treated plants and the control plants or was higher or lower in the former than in the latter.

The dry weight of a plant is a true indicator of the assimilatory activity of a plant as carbohydrates produced are utilised in growth and are converted into cellulose or protein matter. Hence the determinations of the dry weight for both under-treated and untreated conditions would show the effects of the treatment. The relation of leaf weight to the total weight of the plant is also important in understanding the effect of treatment.

The efficiency of the plant for producing open bolls can also be determined by finding the number or the weight of bolls produced by the 100 gm. of the total dry weight of the plant. This would indicate if the application of the hormones had in any way either increased the efficiency of the plant for boll production alone or they had increased both vegetative growth and boll production to an equal extent, thus producing no effect in plant's efficiency.

As this investigation was undertaken to determine the carbohydrate metabolism of the cotton plant grown in Malwa under rainfed conditions and to find out if similar non-utilisation of carbohydrates occurred even in plants growing in such adverse weather conditions as it was found by previous workers [Eaton *et al.*], a study of the effects of three hormones, viz. 2-3-5-triiodobenzoic acid, naphthalene acetic acid and α-3 indolyl butyric acid, was also undertaken side by side. The need for such a study was greater in view of the recent findings by Dastur and Ved Prakash [1954] at Indore.

Material and Methods

This investigation was conducted for two years during the cotton seasons of 1951-52 and 1952-53. During the first year a field experiment was specially laid out for getting material for testing various methods of carbohydrate analysis. The field experiment included three treatments :

(1) Control,
(2) 25 P. P. M. of 2-3-5-triiodobenzoic acid, and
(3) 50 P. P. M. of 2-3-5-triiodobenzoic acid.

In the second year 1952-53 the field experiment consisted of four treatments :

(1) Control,
(2) 2-3-5-triiodobenzoic acid,

(3) α-naphthalene acetic acid, and

(4) α-3 indolyl butyric acid.

The concentration of the chemical hormones used for spraying the crop was 25 P. P. M. There were four replicates of each treatment. Thus the total number of plots was 16. Each plot measured 30 ft. by 15 ft. and accommodated 10 rows of cotton out of which two end rows on the two sides were kept as non-experimental rows. As the rows were 1½ ft. apart the experimental rows in two adjoining plots were separated from one another by a distance of 3 ft. Thus spraying of each plot by a hormone could be done without in anyway contaminating the adjoining plots. As a precautionary measure the plot to be sprayed was separated from the rest of the plots by a gunny bag screen from all sides.

The cotton crop was planted on 20th June 1952 after the first showers of rain were received. The plant to plant distance was kept at 6 in. The first foliage leaves appeared in July and the first sample was taken as shown below on the 1st August. The cotton plants were then sprayed on 8th August. Each plot was sprayed with a particular hormone according to randomisation in the morning. The total quantity of solution for each plot was 0·826 gallon which came to 80 gallons per acre. The control plots were sprayed with pure water.

Fifteen plants were randomised from each plot, as there were four replications of each treatment. Sixty plants were uprooted to form an aggregate sample for carbohydrate and nitrogen analysis and for dry weight determinations. Sixteen plants out of 60 were taken at random for dry weight determinations, i.e. four plants from each replicate for each treatment. The fresh weights of leaves, stem portions above the ground and the reproductive parts, i.e. buds, flowers and bolls when they appeared from 16th September were first recorded after separating them. They were then air dried and oven dried before weighing and dry weights of each portions were recorded. The leaf weight, stem weight, the weight of the reproductive parts and total dry weights were obtained.

The remaining 44 plants were then divided into two lots for carbohydrate and nitrogen analysis so that each analysis can be done in duplicate series. The leaves, stem portions and flowering parts were first separated from each series and fresh weights of each part were recorded. The material of each part was thoroughly mixed after chopping with a cutter and a representative sample weighing 20 gm. was taken for carbohydrate extraction and subsequent analysis. Similarly another representative sample was separately taken and dried for total nitrogen and protein nitrogen analysis. The material taken for carbohydrate analysis was extracted with alcohol as described below to extract the hexoses and disaccharides. After extraction it was dried and the dry weight was determined. The dry weights recorded after extraction were used for calculating the percentage of different carbohydrates in each part of the plant. Thus concentration of each carbohydrate was determined for each part.

From the representative sample taken for nitrogen and protein analysis, a weighed amount of dried sample was first taken for total nitrogen analysis of each part of

the plant. Similarly a sample was taken for portein nitrogen analysis. The samples of cotton plant for chemical analysis and dry weight determinations were taken every fortnight beginning from 1st August up to 16th December. The crop was almost dried up by the last date of sampling. Thus there were 10 samples collected during the season. They were taken in duplicate making 20 samples.

Reducing sugars were estimated by Somogyi's micro-method [1945]. Similarly the cane sugar was determined by the same method after conversion with tartaric acid. Starch was hydrolyzed by taka-diastase and estimated by the method of Shriner [1932]. Nitrogen was determined by Kjeldahl's method and protein nitrogen by Stutzer's method [1935].

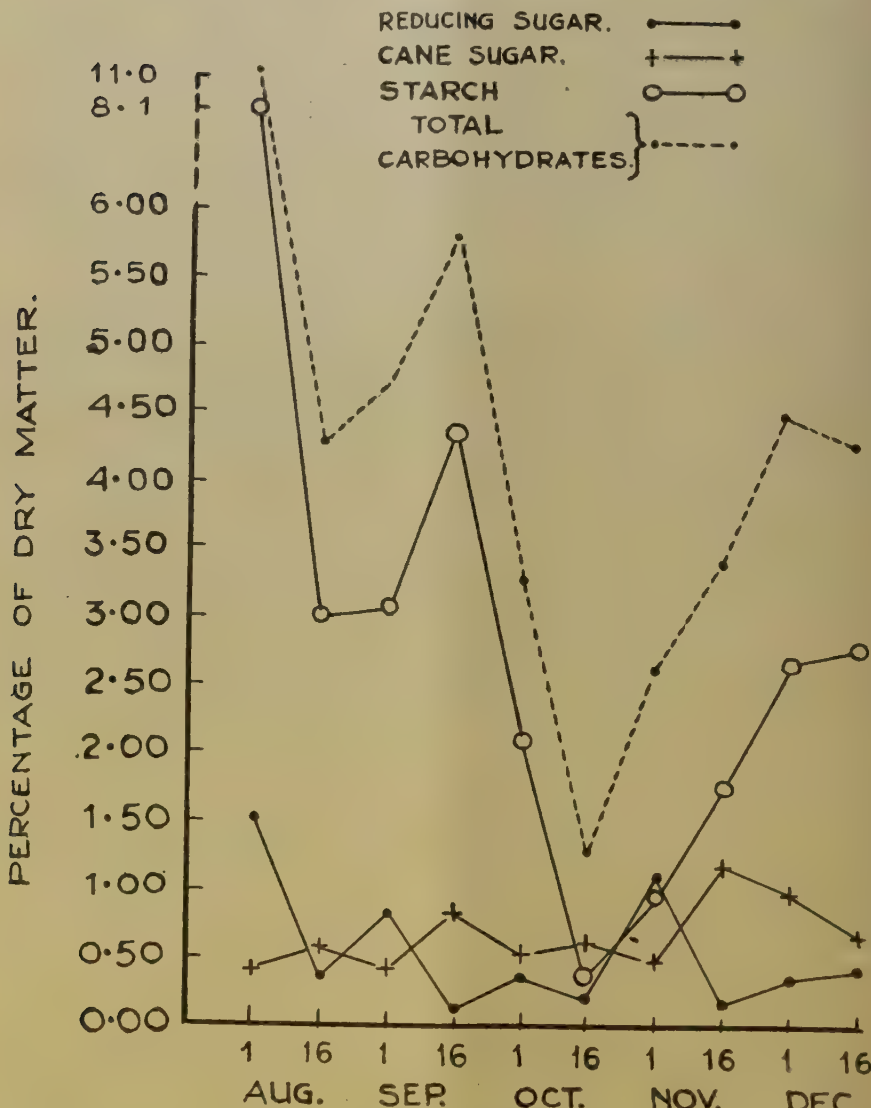
Periodic changes in Carbohydrate contents of Cotton plant

The periodic changes in the carbohydrate contents of the leaves starting from 1st August when the plants were in four-leaf stage up to the second picking of bolls on the 16th December were studied both on the fresh weight as well as dry weight basis. As it was found that the trends in all the different carbohydrates in the leaves at different stages of growth were similar when they were studied on either as percentages of the dry weight or the fresh weight, the results on the residual dry weights are studied and discussed here. The carbohydrate concentrations of the leaf at different stages of growth on dry weight basis are given in Fig. 1.

During early stages there was a small decrease in reducing sugars from about 1·60 per cent to about 0·35 per cent after which the concentrations of reducing sugars fluctuated within narrow limits. The early fall in the reducing sugars may either be due to their utilisation in respiration or their conversion after translocation into starch in the stem. A small rise in concentration of reducing sugars was noticeable at the boll formation stage, i.e. 1st November, after which a sudden decline occurred. The rise in the reducing sugar curve at the bolling stage may be due to a rapid conversion of starch to sugars for translocation to the developing bolls ; the decline in concentration later indicated depletion.

The concentration of sucrose fluctuated between 0·40 per cent to 0·85 per cent in the leaves from 1st August to 16th October, the highest concentration during that period being found on the 16th September, i.e. stage later than the stage at which higher concentration of reducing sugar in the leaves was found. Similarly maximum concentration of sucrose occurred a stage later, i.e. on the 16th November. Thus maximum of both sugars was reached in November, i.e. at the time when bolls were maturing, after which the leaves contained very little sugar.

The curve depicting starch concentrations of the leaves at different stages showed sharp rise and fall quite different from those discussed for hexose and sucrose. It resembled the hexose curve in the early stages. There was a fall in the concentration of starch in the month of August with a rise on the 16th September, i.e. at the same stage when higher concentration of sucrose was found. This rise was followed by a steep fall in October-November. This may be due to its conversion into sugar for translocation to the growing points on account of high vegetative



SAMPLING DATES

Fig. 1. Carbohydrates in leaf of control plants

activity and on account of the setting in of the reproduction phase. The growth was so rapid that the starch was utilised so much so that production of dry matter on 16th October also fell off. It is remarkable that the leaves contained a fairly large amount of starch unutilised at the boll opening stage, as there was a steady rise in starch concentration after the fall on 16th October.

The curve for total carbohydrates showed the same pattern as the curve for starch concentration. This was expected as the concentration of starch was very high in comparison with the concentrations of sugars. Consequently its effect was reflected on the total carbohydrate curve.

The remarkable feature of this investigation was a very high concentration of carbohydrates found on 1st August stage. It was nearly 10·5 per cent of the total dry weight of the leaves. Where did they come from as the month of July was cloudy with low temperatures very unfavourable for photosynthetic activity? It is possible that the main source was the seed which contained large amount of oil which is known to be converted into carbohydrates which are generally utilised for growth. As very little vegetative growth occurred during that period, they may have been stored up in the leaves but later on they appear to be utilised rapidly.

It was evident that there was a great accumulation of carbohydrates in the leaves when the plant had nearly reached the stage of senescence. At this stage, most of the leaves were old and had reddened. Thus even under climatic conditions prevailing at Indore, much of carbohydrates appeared to remain unutilised. Most of these carbohydrates were found to be in the form of starch and cane sugar.

The carbohydrate concentrations of the stem including hypocotyledonary region are given in Fig. 2. The reducing sugar fluctuated, after the early fall, within still narrower limits than reducing sugar in the leaves. A small rise was evident on the 1st November as was the case in the leaf.

The cane sugar curve of the stem also showed similar trend. After an initial fall it remained constant uptil November when a small rise was noticeable. It was characterised with a fall from 1st August up to 16th October. Cane sugar concentrations in the stem stood always higher than the concentrations of reducing sugars. It appeared that cane sugar being a translocatory form of carbohydrate, did not accumulate in the leaves and was rapidly transported to the stem. It showed that on account of high photosynthetic activity the sugar first accumulated in the stems and later in the leaves. This was followed by a steep fall in the sucrose content. It fell from 1·2 to 0·65 per cent in the leaf and from 2·5 to 0·6 per cent in the stem. The utilisation of sugars was very great during the first fortnight of November which appeared to be a period of greatest metabolic activity.

The starch concentration in the stem portions showed a rise in the first fortnight of August. This was the reverse of what was found in the leaf where a steep fall in starch content was found. It was likely that transfer of carbohydrate occurred from the leaf for storage in the stem parts. Starch content began decreasing in the stem from that date indicating its utilisation for growth so much so that it was practically nil in the first half of October. It became nil in the leaf a fortnight later, i.e.

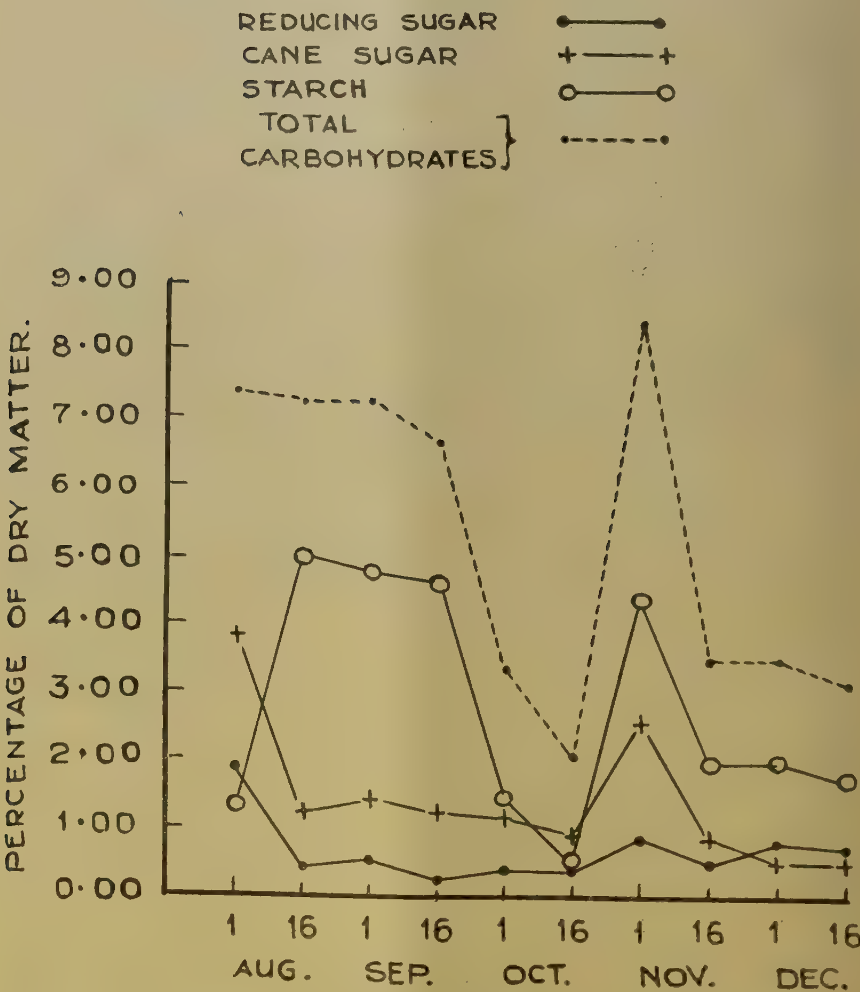


Fig. 2. Carbohydrates in stem of control plants

in the second week of October. This simultaneous disappearance of starch both in the leaf and stem was another important finding of carbohydrate metabolism of the plant. There was again a rise in the starch content in the stem in the second half of October with a steep fall in the next fortnight after which it remained constant. No such fall was visible in the leaf where it continued to rise up to the end of the season. The starch content in the leaf was higher than the starch content of the stem at the end of plant's life cycle.

The total carbohydrates in the stem showed a small decline from August and they fell rapidly in September when the plants began to flower. They were lowest in October. They showed a rise like starch contents and sugar concentrations in November after which they declined. There were about 3 per cent carbohydrates in the stem at the end of the season, little less than what remained in the leaf.

In the study of the periodic changes in the different carbohydrate contents of the reproductive parts, buds, flowers and developing bolls are mixed together. The buds and flowers first appeared in the collections made on the 16th September. This analysis did not, therefore, include the shed flowers and bolls. Thus the carbohydrate contents of those fruiting parts which were present on the plants on the date of collection are alone studied.

The curve for reducing sugars and cane sugar in the reproductive parts are given in Fig. 3. The concentration of reducing sugars in the flowering parts was a little higher than what was found in the stem and the leaves on the 16th September after which the concentration showed a decrease in the fruiting parts so much so that it was nil on the 1st November when this sugar showed a small rise in the leaves and stems. There was a small rise later, which corresponded with a similar rise in the leaf and stem a stage earlier. At the end of the season very little hexose sugar remained and this must be present in the carpels as reducing sugars were generally not found in the seeds.

The cane sugar curve in the reproductive parts showed similar features as the reducing sugars except for a rise in the cane sugar in October after which it fell to the same level as the reducing sugar with a similar rise on the 16th November. The reproductive parts, i.e. carpels plus seeds contained about 0·6 per cent of cane sugar at the end.

The starch contents of the flowering parts also showed a continuous fall till the end of this season, when it fell to zero. Thus all the starch appeared to have been utilised in the seed development. The starch content was about 6·1 per cent at the beginning of the flowering phase. Thus all carbohydrates travelled to the reproductive parts and stored up as starch which was later utilised in the development of bolls. This was evident from the total carbohydrate curve given in the Fig. 3. At the end, there were left about 1·0 per cent carbohydrates and this may be present in the carpels or in some bolls that may not have opened when the last sample on 16th December was taken.

This investigation has shown that the main source of carbohydrate food required for the cotton plant during the early stages appeared to be the seed. As very little

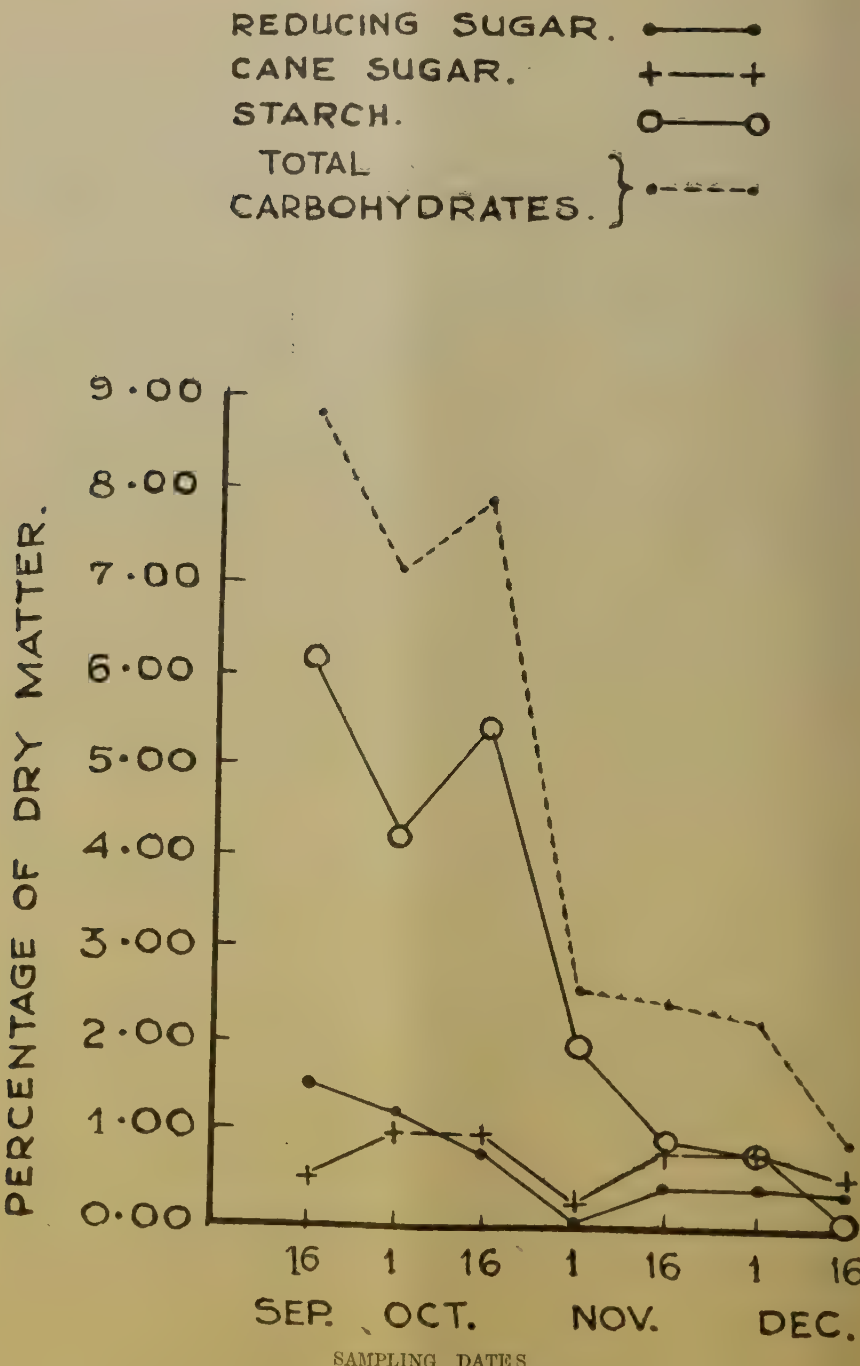


Fig. 3. Carbohydrates in flowering parts of control plants

growth occurred during the month of July-August, the carbohydrates derived from the oil which was stored up in the seed, accumulated in the leaf and stem portions of the plant mostly in the form of starch. These were being rapidly utilised when the conditions became favourable for growth. The increase in the carbohydrate contents of the leaves from 1st September indicated a high photosynthetic activity due to a rise in temperature which went upto 90°F on account of tne return of bright weather (Fig. 2). As the input of carbohydrates was not sufficiently large to meet the requirement of the growth, the carbohydrate content of the leaf and the stem decreased from 16th September so much so that it became nil on 1st October and consequently the percentage increase in dry matter became also nil during the next fortnight as can be seen from Fig. 21. After 16th October there was a steady accumulation of starch in the leaves. There was about 2·8 per cent of starch left in the leaves at the end of the season. In the case of stem a great concentration of carbohydrates was noticed on the 1st November after which there was a downward trend. The stem parts contained about 1·8 per cent of starch at the end of the season. Thus there was enough food material stored up in the stem and leaves but it remained unutilised.

Effect of Chemical Hormones on Carbohydrate content

Analysis of different parts of cotton plants sprayed with three chemical hormones, viz. TIBA, NAA and IBA for different carbohydrates revealed that these hormones produced some effect on carbohydrate production even though they were known to be rapidly utilised in forming cellular structure and in respiration. The leaves of all the three hormone treated plants showed a higher carbohydrate content than the leaves of the control plants at certain stages only, indicating a higher photosynthetic activity at that stage than the leaves of control plants. This effect of hormones was evident during the stage of the plants when they displayed maximum metabolic activities, i.e. in October-November, when the plants were in the reproductive stage and when the percentage increase in the dry matter also was found to be the highest.

The concentrations of reducing sugar and cane sugar in the leaves at different stages under different treatments did not show any marked difference except at one stage, i.e. on 1st November. The maximum concentration of sugars occurred on the 1st November under all cases but concentrations of sugars in the hormone treated plants were higher than the concentration of sugars in the leaves of control plants (Fig. 4 and 5).

The same remarks applied to the starch contents of leaves under different treatments except that the periods for the lowest and the highest starch contents were shifted forward by a fortnight (Fig. 6 and 7). On 16th October and 1st November starch content was lowest while it was highest on 16th November. The plants treated with α-3 indolylbutyric acid showed highest starch content while it was higher in TIBA and NAA treated plant than in the control. A sharp fall in starch content after 16th November was another feature of the treated plants different from

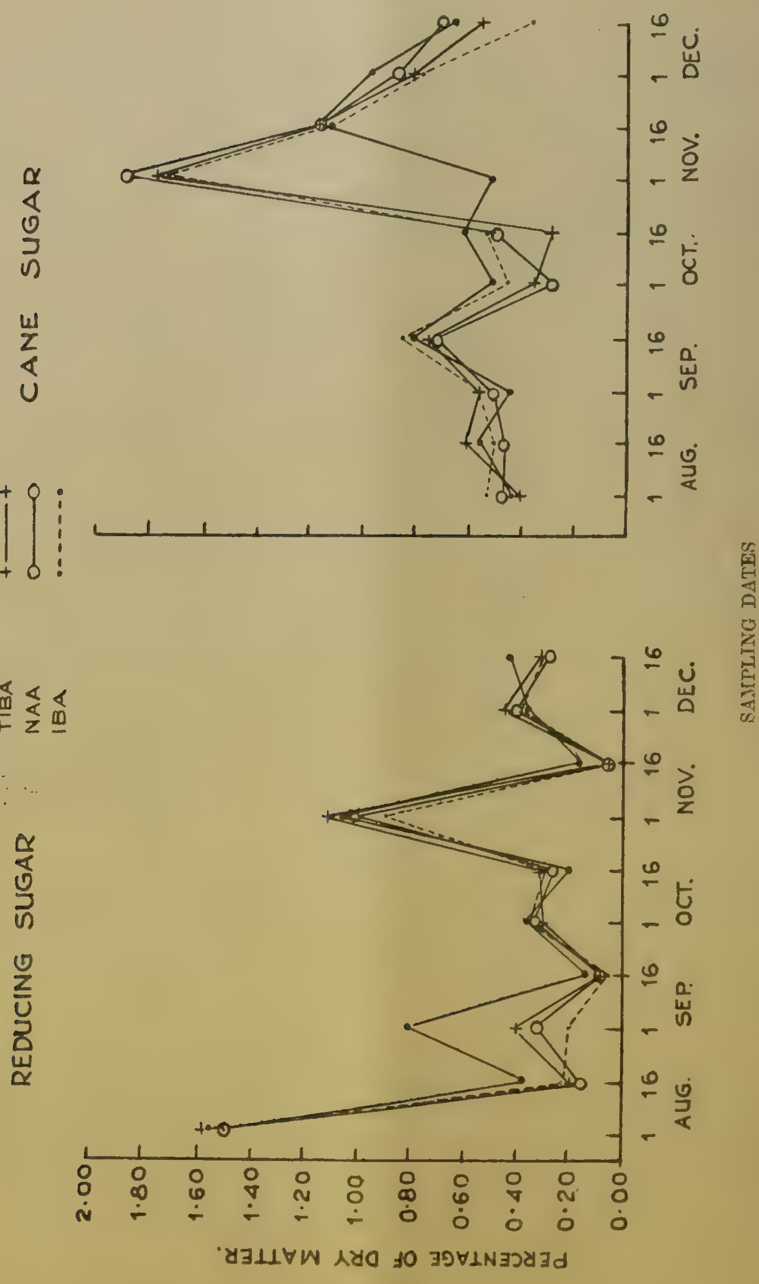


Fig. 4. Leaf

Fig. 5. Leaf

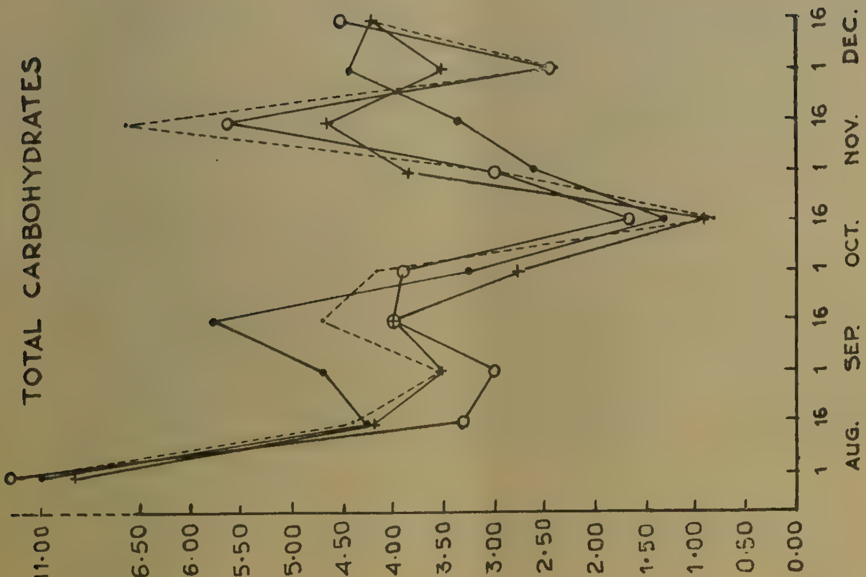


Fig. 7. Leaf

SAMPLING DATES

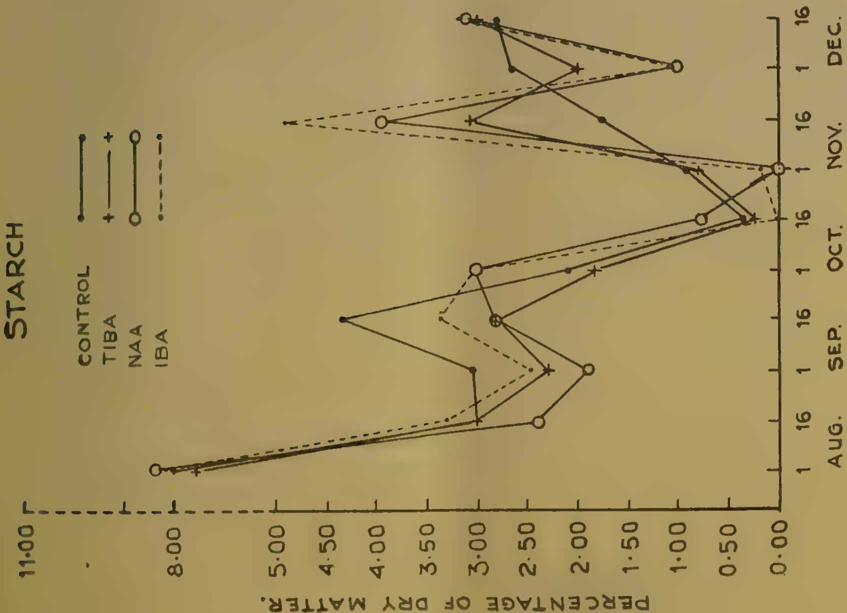


Fig. 6. Leaf

the control plants where there was a continuous rise in the starch content. At the end of maturity the starch contents of the leaves of all plants tended to be nearly equal (Fig. 6 and 7).

It appeared that chemical hormones had produced a marked effect on the photosynthetic activities of leaves during the most active period of the life cycle of the plant on account of their greater accumulation in the leaves. This view is also supported by the analysis of the stems of the treated and control plants and their dry weight studies discussed later.

The effect of spraying the cotton plant with chemical hormones on the reducing sugars and on cane sugar in the stems was clear from Fig. 8 and 9. The effect was evident during the fruiting stage, i.e. from 1st October to 1st December, when the sugar contents were higher in the hormone treated plants than in the control. Thus the use of chemical hormones has given rise to a higher concentration of sugars in the stems. This feature was not so pronounced in the case of the leaves.

The starch content curve of the stem did not resemble the cane sugar curve (Fig. 10). The greater accumulation of starch in plants treated with chemical hormones did not occur at any stage as was the case with hexoses and sucrose. But this effect was visible at the end of the life cycle when the stems of treated plants contained more starch than the stems of control plants (Fig. 10). Nearly 4·0 per cent of starch remained stored up in the stem of NAA treated plants as compared with 1·8 per cent in the stems of control plants.

Thus the best evidence of the effect of hormones on the carbohydrate contents of the plants was visible in the leaves when the two carbohydrates, viz. cane sugar and starch, were higher in the treated plants. Similar effect was visible in the hexose and sucrose concentrations of the stem but not so on the starch. As the leaf was the chief photosynthetic organ, the effect of the higher photosynthetic activity produced by these treatments was seen in the leaves.

The effect of hormonal treatment on the different carbohydrate concentrations of the flowering parts are given in Fig. 12, 13, 14 and 15.

The reducing sugar contents of the reproductive parts of the treated plants were found to be consistently higher at all stages of reproductive activity than the reducing sugar concentrations of the corresponding parts of the control plants. It was clear that more carbohydrate food in the form of hexoses was available for the development of flower and bolls when the plants were sprayed with these hormones. The plants treated with IBA showed the highest concentration of reducing sugars.

The values of cane sugar concentrations in the reproductive parts under different treatments did not show any marked differences, while the starch contents appeared to be higher in the TIBA treated plants only.

As the hexoses provided the chief building material, their higher concentration at all stages in the treated plants was a remarkable result. It indicated that more carbohydrate food was available for the growth of the reproductive parts in the hormone treated plants. If this were a true effect, there was expected to be an

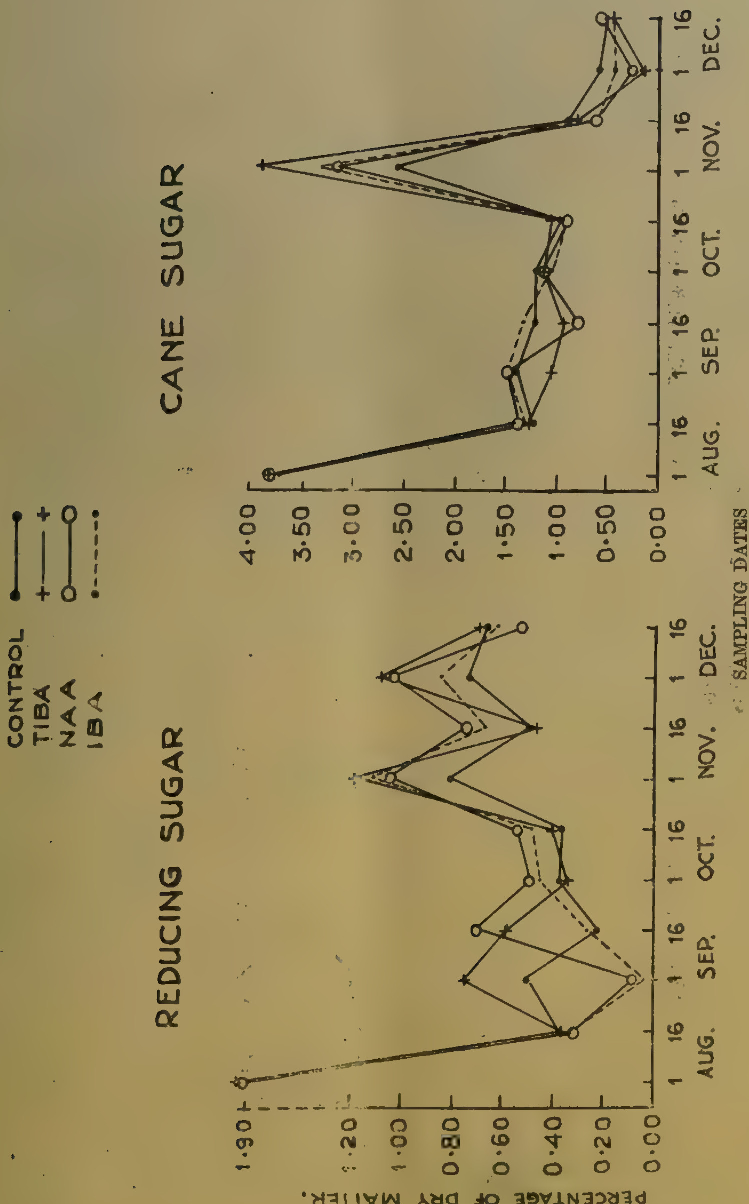


Fig. 8. Stem

Fig. 9. Stem

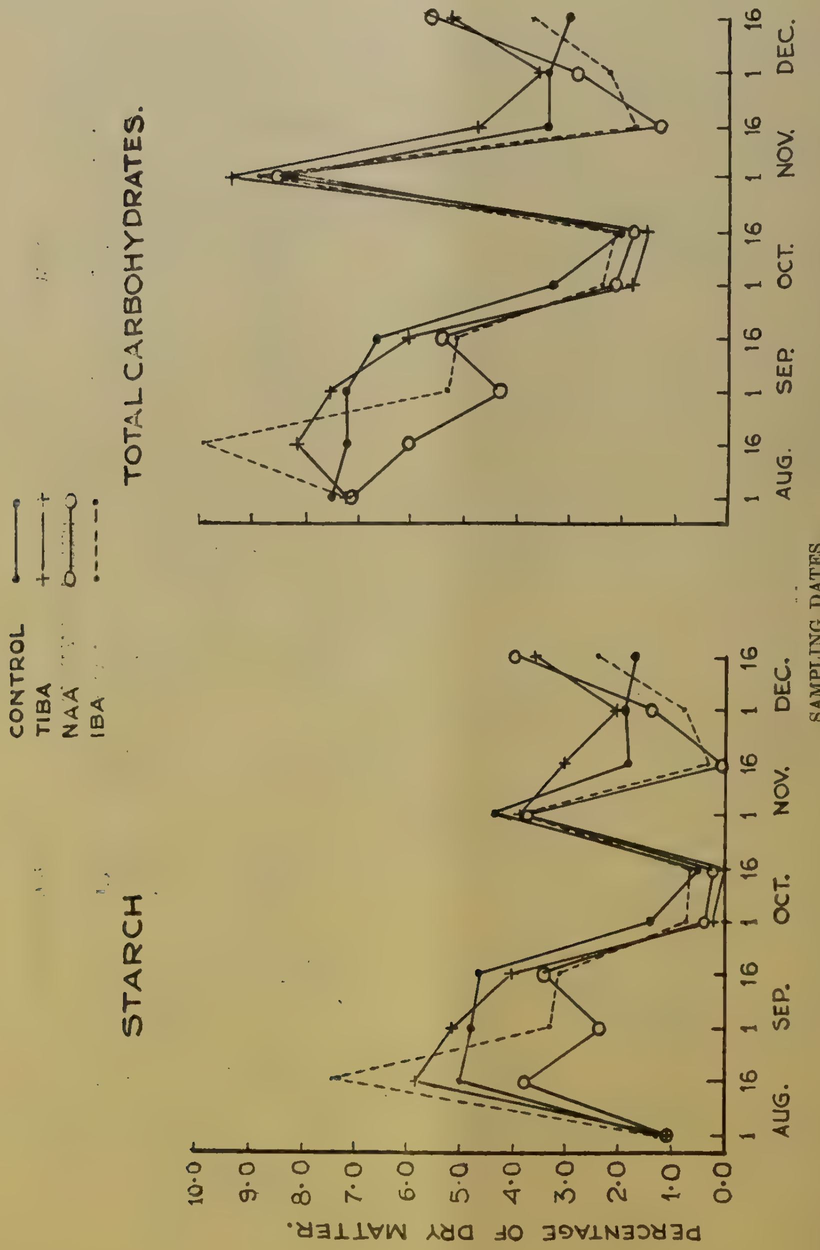


Fig. 10. Stem

Fig. 11. Stem

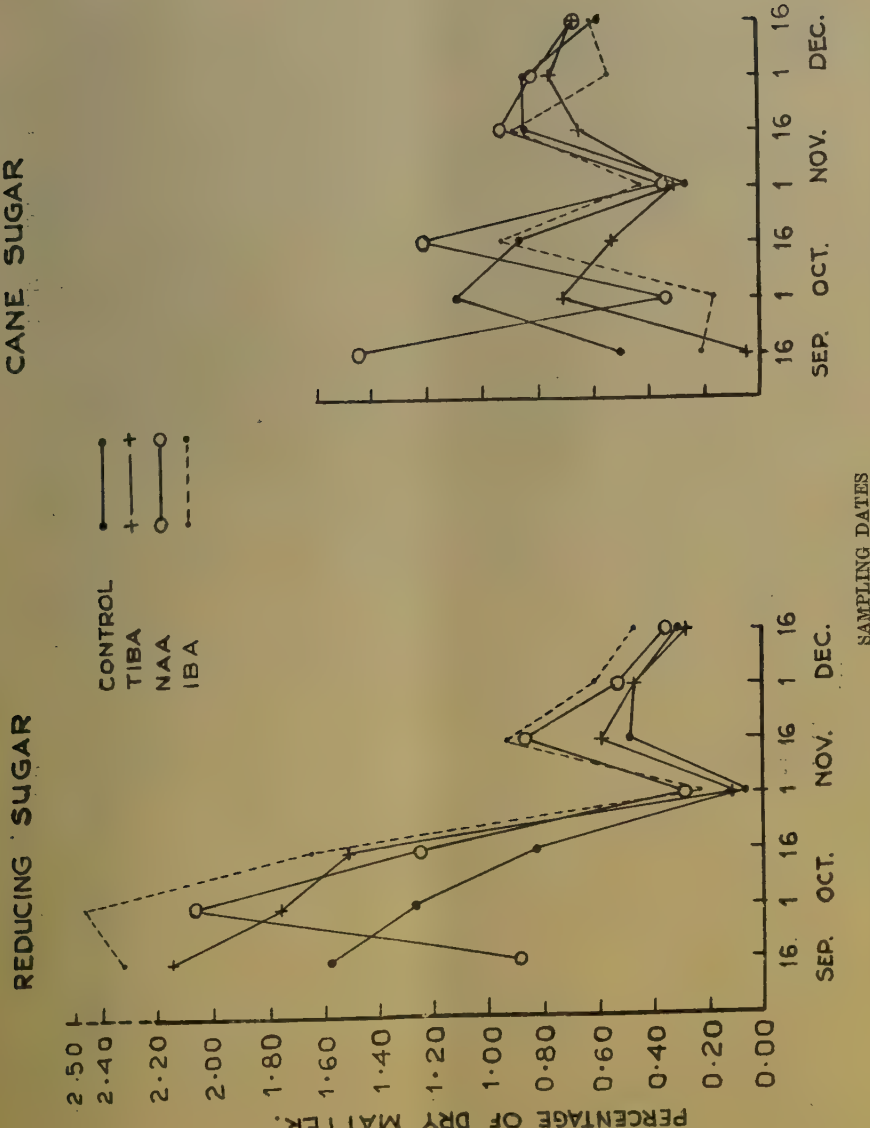


Fig. 12: Flowering parts

Fig. 13. Flowering parts

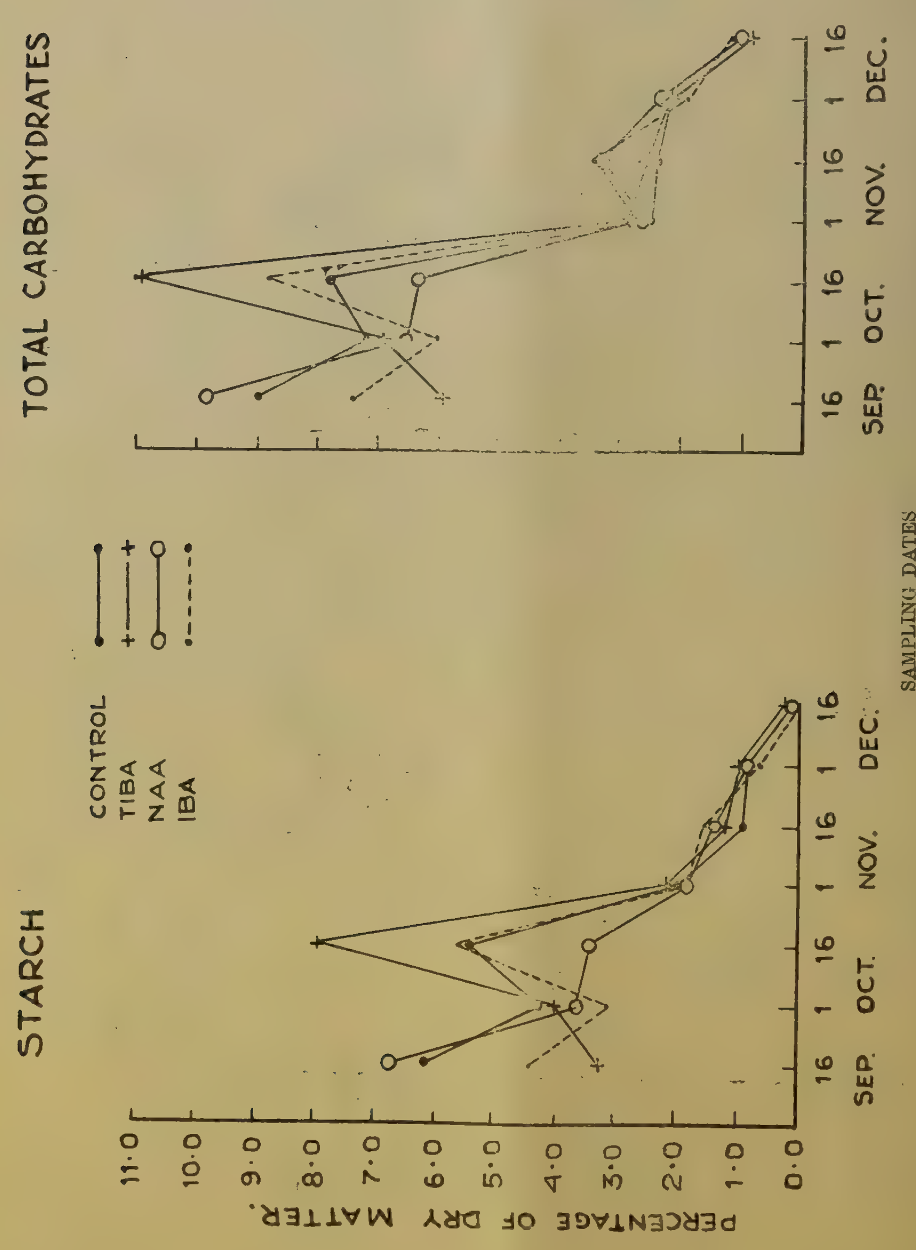


Fig. 14. Flowering parts

Fig. 15. Flowering parts

increased reproductive activity in the treated plants than in the control plants. This was actually found to be the case as will be shown later.

Effect of hormones on production of dry matter

Any treatment that increases the photosynthetic activity of the leaves must also effect the growth made by the plants as the metabolic carbohydrates supply the chief material which builds the plant body. The growth of the plant can be measured by the total dry matter it accumulates. This has been done in this investigation by taking the dry weights of an adequate number of randomised plants from each replicate. The dry weights of the leaves, stem portions and fruiting parts and the total dry weight per plant were recorded at each stage of growth, i.e. at fortnightly intervals. The total dry weight per plant under each treatment at each stage is given graphically in Fig. 17. The dry weights per plant in the control and treated series did not show any marked differences up to 1st October. Thus the effect of treatment was not visible in the total dry matter produced upto that stage. The effect of hormones became visible when the plants came in the reproductive phase. The dry weights of the treated plants became higher after this date than those of the control plants and remained higher up to the end. This was thus a clear indication of the increased metabolic activity of the plants treated with hormones.

The plants treated with NAA attained the highest dry weight (Fig. 17). It produced six grams of more dry matter per plant than the control plants while the weight per plant in the case of other two hormones was nearly 23·5 gm. as compared to 20 gm. in the case of control. Thus the increased production of dry matter per plant in the hormone treated plants suggested a definite increase in the formation of carbohydrates by photosynthetic activity.

As the total dry weight per plant was the sum of the total dry weight of the leaves, stems and fruiting parts, it is necessary to determine the effect of hormones on the growth of these three parts separately. It is to be determined whether the application of hormones effected the growth of the leaves, stems or the flowering parts, or of any two of those organs or of all organs. The effects of the three hormones in comparison with the control on the leaves stems and the fruiting parts can be seen from Fig. 16, 18 and 19. No effect on the growth of leaves of any one of the chemical hormones is seen up to 1st October. Some enhancing effect on the leaves was visible during the next stage, i.e. 16th October and 16th November. There was thus an indication that leaf growth was favourably affected at the stage when the leaf growth reached its maximum. As the leaf weight was known to be proportional to the leaf area, the total leaf area must be higher in the treated plants than in the control plants at the time of maximum leaf area stage. Greater the leaf area, greater would be the photosynthetic activity and this may also account for the greater dry weight per plant in the hormone treated plant.

The greater leaf area and consequently greater photosynthetic activity on account of hormone application has resulted in better flowering and fruiting activity

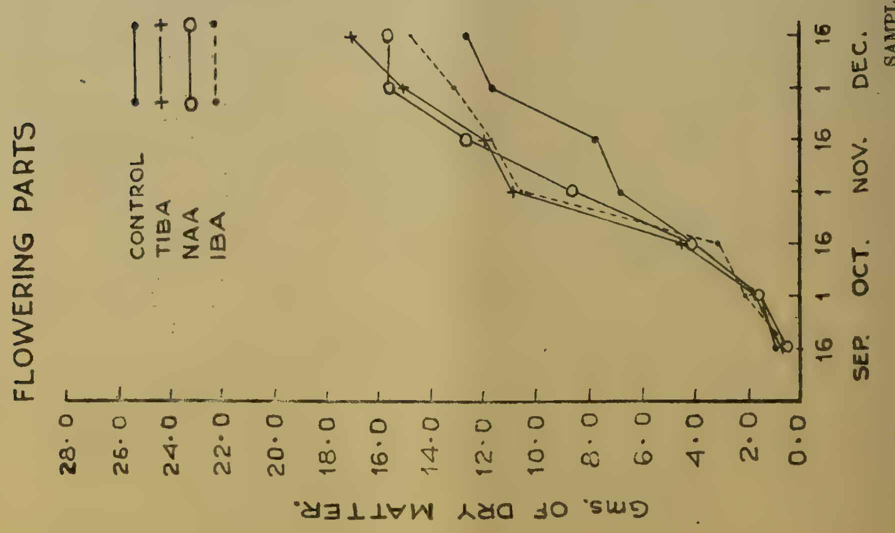


Fig. 16. Dry weights per plant (in grams)

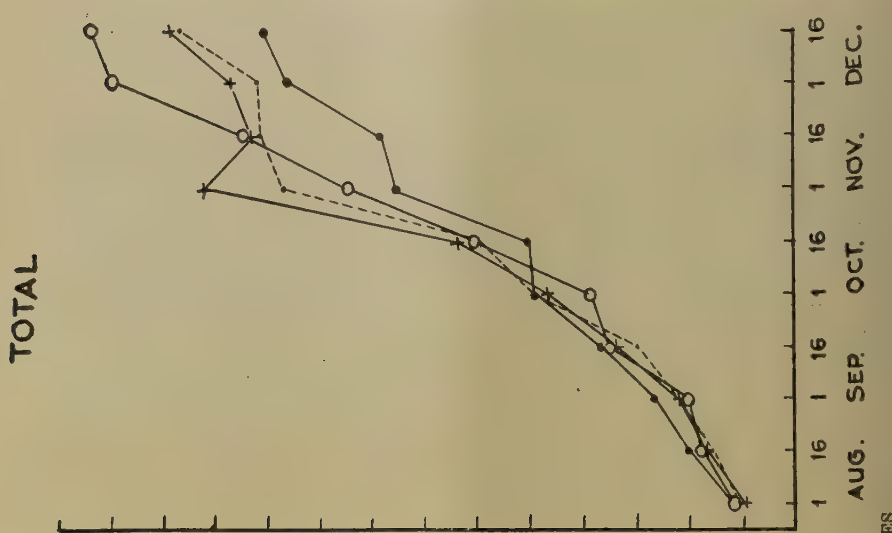


Fig. 17. Dry weights per plant (in grams)

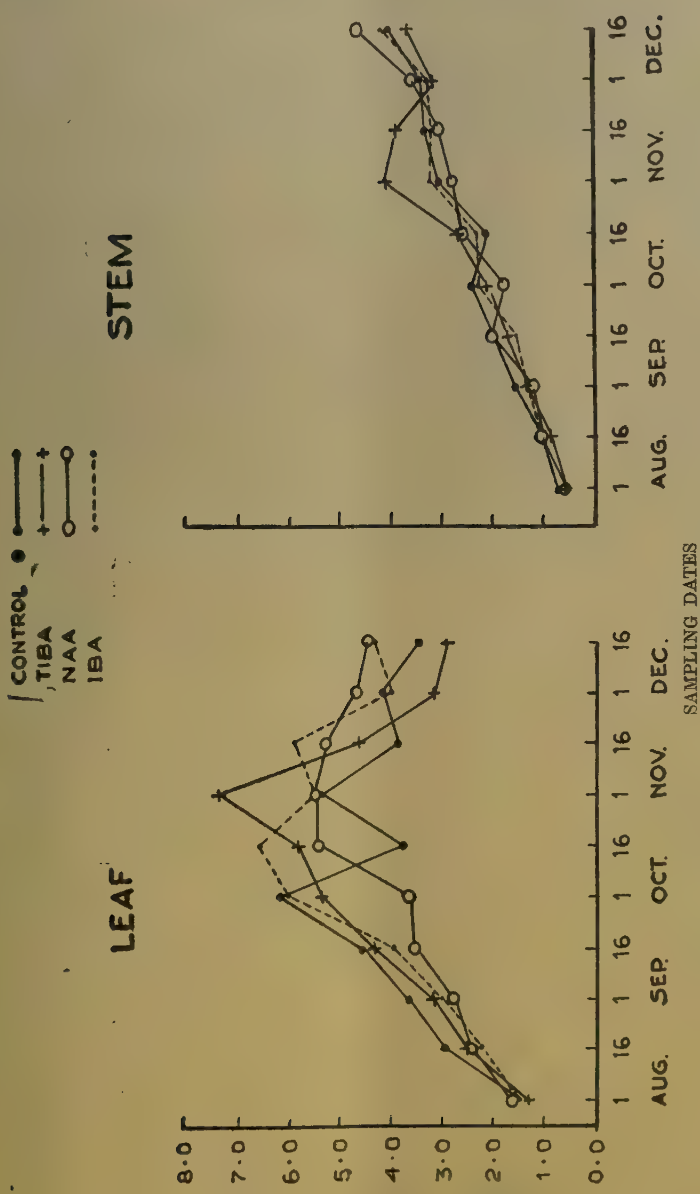


Fig. 18. Dry weights per plant (in grams)

Fig. 19. Dry weights per plant (in grams)

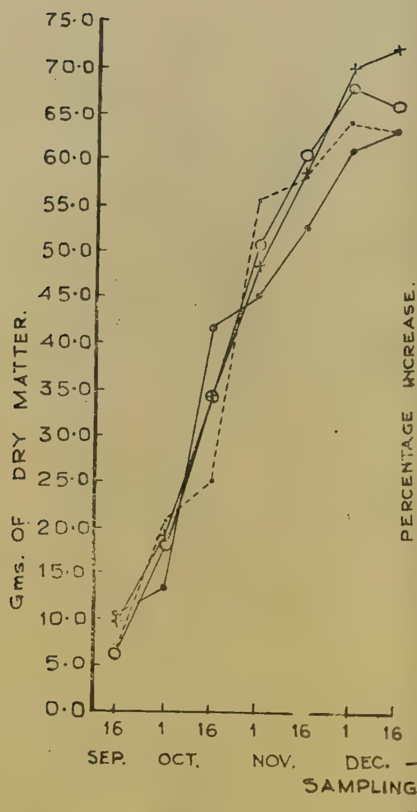


Fig. 20. Flowering parts per 100 gms. of total dry weight

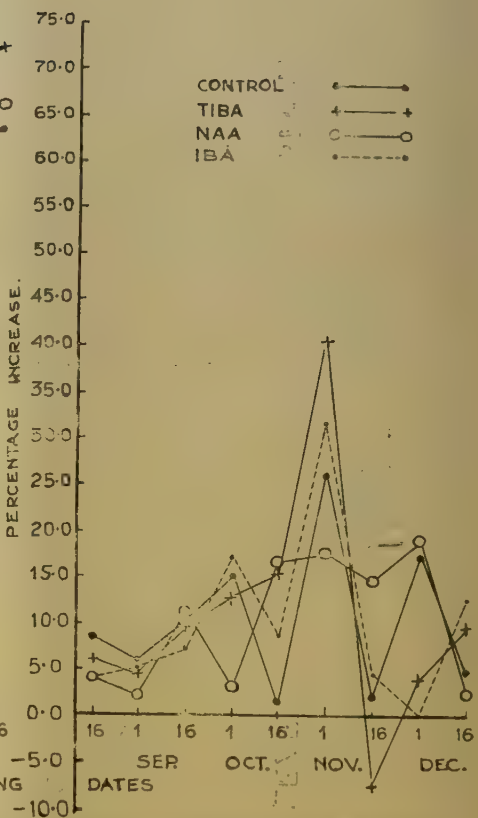


Fig. 21. Percentage increase in total dry weights

in the treated plants as was evident from the dry weight curves of the flowering parts given in Fig. 17. The dry weights of the flowering and fruiting parts of the hormone treated plants were higher than the dry weights of the corresponding parts in the untreated plants during the last four stages, i.e. from 1st November to 16th December. All the three hormones had enhanced the fruiting activity and greater dry matter per plant produced under hormone treatment was mainly due to the greater dry weight of the reproductive parts.

When the dry weights of the reproductive parts were calculated per 100 gm. of the total dry weights of the plant under each treatment, it was found that the treated plants produced greater percentages of the dry weights of the reproductive parts than those of the control plants (Fig. 20). Thus it was definite that the main effects of these hormones were on photosynthetic activity resulting in greater production of carbohydrates and consequently the total dry matter; especially the dry matter of the reproductive parts. It clearly indicated that the efficiency of cotton plant for reproductive growth was greater in the hormone treated plants.

It was necessary to determine if the differences in the total dry weight per plant between the control and hormone treated plants were statistically significant. The total dry weight per plant was, therefore, analysed for each date according to Fisher's method and standard error as well as the critical differences were determined. These results are given in Table I. As four plants from each replicate were weighed separately, the statistical analysis was possible for each date.

TABLE I

Means of the total dry weight per plant (in gm.) under each treatment on the sampling dates

Date	Control	TIBA	NAA	IBA	S.E.	C.D. at 5 per cent
1st August	2·32	1·58	2·20	2·11	0·32	0·73
16th August	3·95	3·28	3·37	3·12	0·27	0·61
1st September	5·70	4·37	4·00	4·27	0·43	0·97
16th September	7·24	6·66	6·95	5·91	1·14	2·59
1st October	9·84	9·32	7·78	9·88	1·25	2·82
16th October	10·05	12·64	12·15	11·42	1·76	2·99
1st November	15·32	22·22*	16·58	19·23	2·43	5·50
16th November	15·76	20·39**	20·80**	20·34**	0·70	1·50
1st December	19·25	21·35	25·92*	20·33	2·13	4·83
16th December	20·09	23·58	26·70*	23·12	1·58	3·57

* Indicates significance at 5 per cent level
** Indicates significance at 1 per cent level

Statistical analysis was done for each sampling date. Even though spraying was done on 8th August the differences in the total dry weight per plant began to appear from the 16th October though they did not reach the level of significance on that date. On the 1st November only the effect of TIBA was significant and the significant difference was maintained on the 16th November and 16th December samples. Similarly the differences in the dry weights of the control and NAA treated plants came out to be significant on the 16th November, 1st December and 16th December. In the case of IBA the differences in the dry weights between treated and control plants reached the level of significance only on the 16th November sample. Thus TIBA and NAA treated plants produced significantly higher dry weights than the control plants while the effect of IBA was significant only on one date.

It was pointed out that the differences between the total dry weights per plant between control and treated plants were mainly due to the differences in the dry weights of the reproductive parts. It was, therefore, necessary to determine if this conclusion stood the statistical test. Table II gives the results of statistical analysis.

TABLE II

Means of the dry weights of reproductive parts in gm. at each sampling dates

Date	Control	TIBA	NAA	IBA	S.E.	C.D. at 5 per cent
16th September	0·760*	0·665	0·498	0·380	0·120	..
1st October	1·372	1·772	1·390	2·098	0·440	0·994
16th October	4·220	4·422	4·122	2·965	0·619	1·399
1st November	6·885	10·815*	8·508	10·658*	1·459	2·391
16th November	7·680	11·582**	12·582**	11·778**	0·501	1·132
1st December	11·788	15·015*	17·702*	13·078	1·397	4.456
16th December	12·645	17·023**	17·590**	14·670**	2·116	0·696

* Denotes significance at 5 per cent level
** Denotes significance at 1 per cent level

The effect of TIBA was significant from the 1st November onwards on the reproductive activity. Similarly the effect of NAA was significant from the 16th November onwards. Thus these two hormones had definitely increased the reproductive growth on the 1st November and the 16th December. On account of high standard error the effect of IBA has not reached the level of significance in the sample collected on the 1st December.

TOTAL NITROGEN AND PROTEIN NITROGEN OF COTTON PLANT

The leaves, stem and reproductive parts were analysed for total nitrogen in order to determine if there was any effect on the nitrogen content as a result of the application of the chemical hormones and to study the relation of nitrogen content to the total carbohydrate contents of each organ and of the plant as a whole. It would also be interesting to study the changes in the carbohydrate/nitrogen ratios during the life cycle of the cotton plant under rainfed conditions directly and under different treatments in the field.

The nitrogen contents of the leaves of the treated and control plants at different stages of growth are given in Fig. 22. The nitrogen content like the hexose and starch content decreased from about 3 per cent to 2·5 per cent during the first fortnight of August, indicating its rapid utilisation during that period. It may also be due to the fall in absorption of nitrogen from the soil on account of unfavourable weather and soil conditions. A rapid rise was again indicated under all treatments after that date, though its concentration did not go beyond 3 per cent in any case, the maximum was reached early in October, after which it began to decrease probably on account of its translocation to the developing fruits. The minimum concentration was reached at the end of the maturation period when it fell to 1·75 per cent in the leaves of control plants and a little higher in the case of treated plants. Just like carbohydrates, the leaves of the treated plants contained slightly more nitrogen than the leaves of control plants at the end of their life cycle, but the difference was small to be of any importance. At no stage in the life cycle of the plant there was any effect of hormone treatment visible as was the case in the different carbohydrate contents of the leaves.

The nitrogen contents of the stems fluctuated within still narrower limits, i.e. from 1·4 per cent at the beginning in August to about 0·75 per cent in December at the end (Fig. 24). Thus the nitrogen contents were lower in the stem than in the leaves.

Thus there appeared to be no accumulation of nitrogen either in the leaf or the stem when the plants were treated with chemical hormones as reported by previous workers.

The total nitrogen contents of the reproductive parts of the control and hormone treated plants showed marked differences from the very beginning of the flowering and fruiting activity (Fig. 26). The total nitrogen content of the reproductive parts was found to be at a higher level from the early stage up to maturity in the hormone treated plants than in the control plants. Thus there was a great similarity between the reducing sugar curve (Fig. 12) and nitrogen curve of the flowering parts. Both the curves are also falling curves.

Nitrogen contents of the reproductive parts declined from the early stage. It dropped from 2·6 per cent on the 16th September to 1·35 per cent on 1st November, after which it remained almost constant in the control plants. The trends in the total nitrogen content of the reproductive parts of the hormone treated plants were also similar though the values of total nitrogen stood higher in the treated

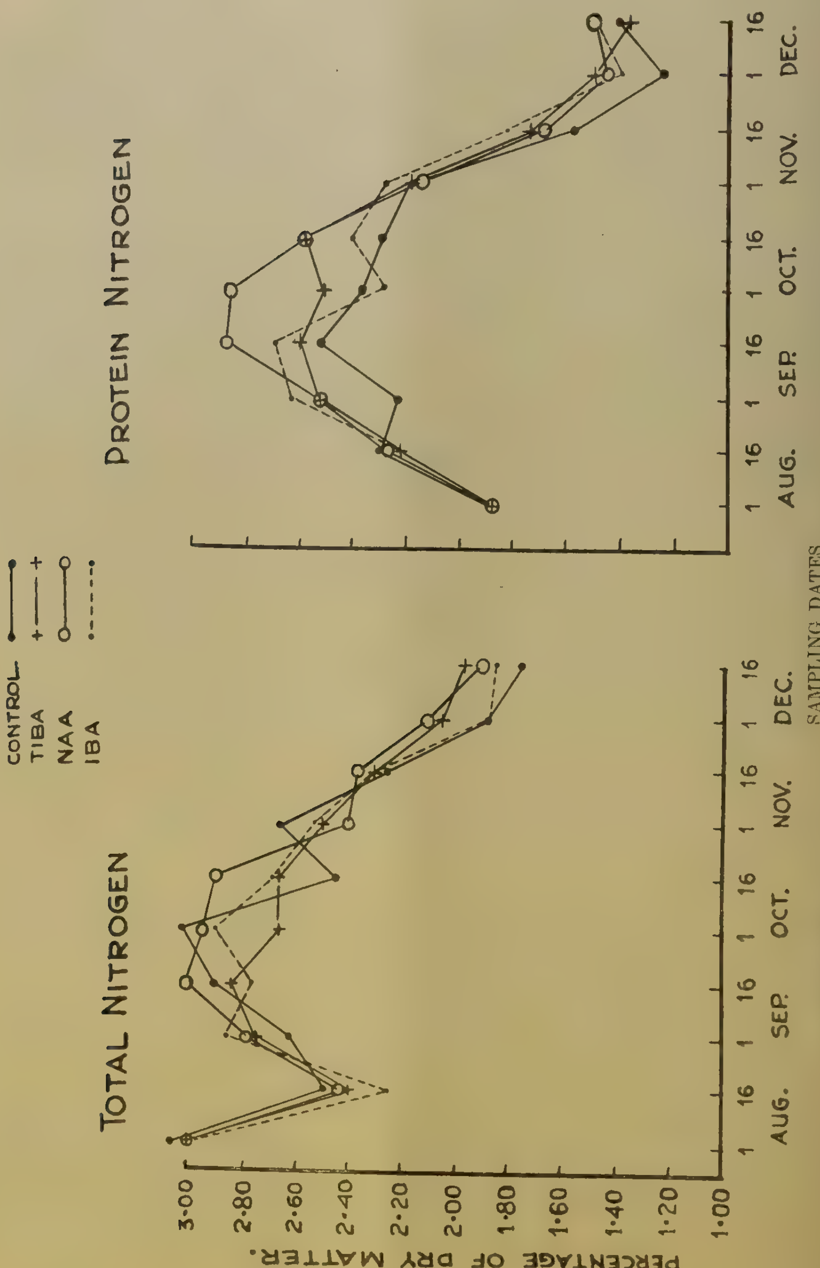


Fig. 22. Leaf

Fig. 23. Leaf

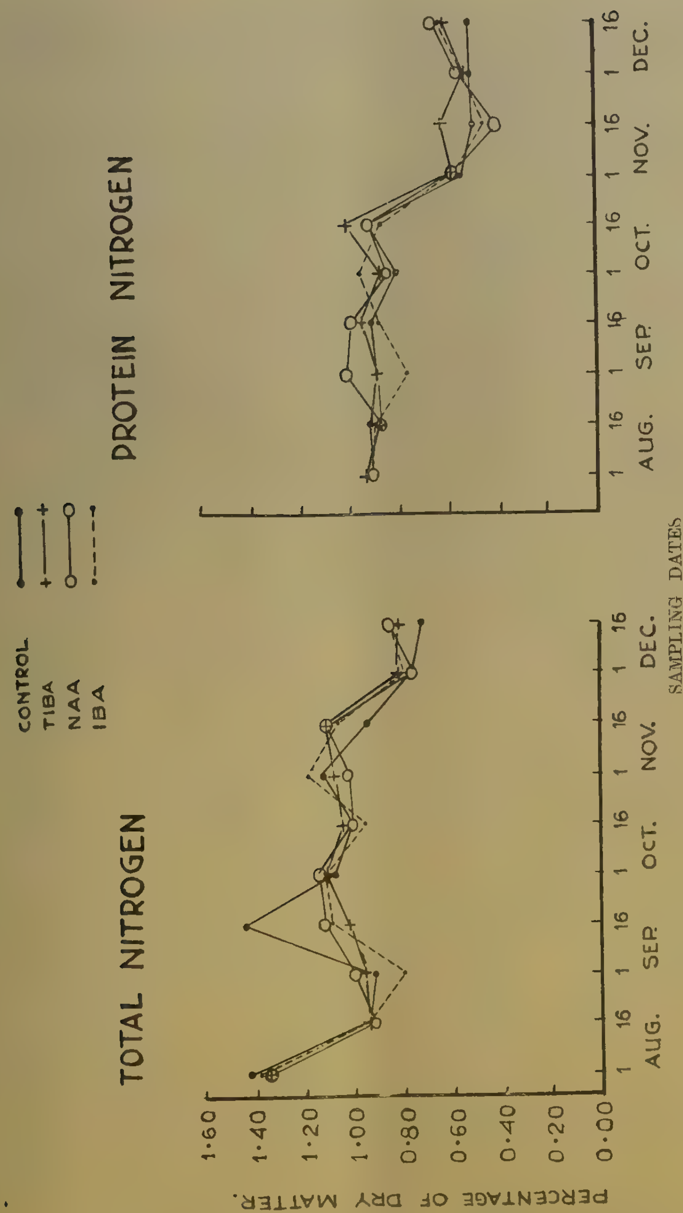


Fig. 24. Stem

Fig. 25. Stem

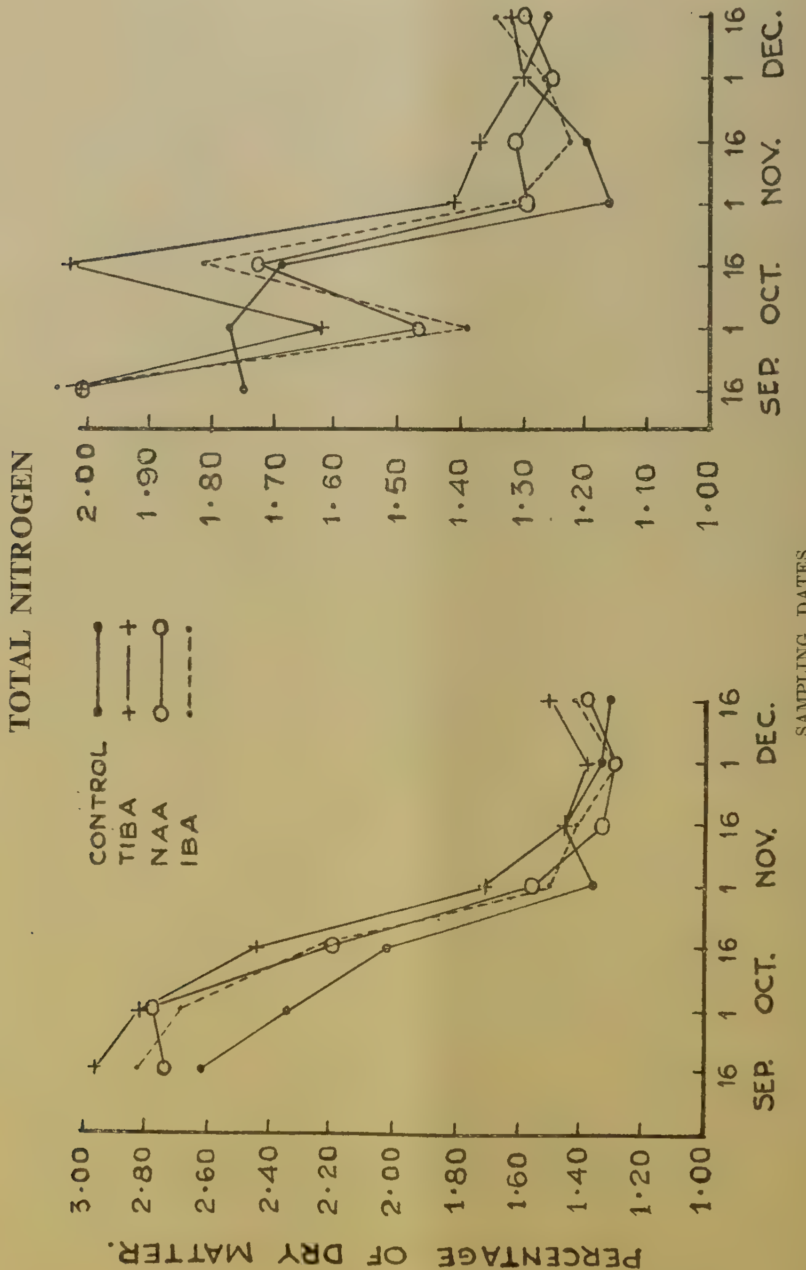


Fig. 26. Flowering parts

Fig. 27. Flowering parts

plants than in the control plants. It was highest in the plants treated with TIBA. Thus hormone treatment produced greater concentrations of reducing sugars and nitrogen in the reproductive parts.

It should be pointed out that the reproductive parts include buds, flowers, carpels and seeds. These results are, therefore, expected to be different from those given either for carpels or seeds alone by other workers [Dastur and Ahad, 1945]. The results of total nitrogen are apt to decrease as samples at each fortnightly stage consist of bolls of different ages. Total nitrogen remained constant from 16th November under all treatments.

The curve for protein nitrogen content resembled the curve of total nitrogen in the leaves, except that there was no depression in the protein nitrogen content of the leaves during the first half of August (Fig. 23). The protein nitrogen like total nitrogen content later increased, reached a maximum and declined rapidly during the maturation stage. The protein nitrogen content increased from 1·87 to 2·5 per cent by the middle of September in the leaves of control plants after which it fell to 1·22 per cent on the first December, indicating that protein nitrogen was rapidly used in the formation of reproductive parts. The effect of all the hormones on the protein nitrogen content was clear from the very early stages. Like the carbohydrates protein nitrogen content was higher in the leaves of hormone treated plants than in the leaves of control plants during the period of maximum activity (Fig. 23). Thus, though the results of total nitrogen did not indicate any differences between the treatments, presence of more proteins in the leaves from 16th August to 16th October indicated that more nitrogen was converted into proteins in the treated plants than in the control plants. More proteins were synthesised and that may be the result of greater carbohydrate activity under hormone treatment even though total nitrogen contents did not show any differences between treatments. It, therefore, appeared from the results that the control plants contained more of non-protein nitrogen in the leaves while all nitrogen in the hormone treated plants was in the form of proteins. These results indirectly suggest that more carbohydrates were available for protein synthesis in the treated plants than in the control. The protein nitrogen of the stem remained almost constant from the early stages up to the middle of October after which it showed a rapid fall (Fig. 25). There was very little protein nitrogen left in the stem after maturation. These results indicated that proteins were stored up more in the leaves than in the stems and the developing bolls got the proteinaceous food materials mostly from the leaves. The stems of hormone treated plants did not show greater accumulation of the proteins than those of the control plants.

Reproductive parts of the control plants were similar indicating that most of the total nitrogen at each stage was in the form of proteins (Fig. 27). The protein nitrogen of the reproductive parts of the hormone treated plants showed depression on the 1st October and this depression corresponded with a similar depression noticed in the total carbohydrate contents on the same date. This was the only

difference. The protein nitrogen content of the reproductive parts of the hormone treated plants stood higher at all stages except on the 1st October.

Thus the greater reproductive activity in the treated plants may be attributed to higher rate of carbohydrate synthesis and consequently of protein synthesis.

Carbohydrate/nitrogen ratio in cotton plant at different stages of growth

As the results of carbohydrate analysis and total nitrogen of the different parts of the cotton plant were available, it would be interesting to study the changes in the C/N ratio of the different parts of the plant and of the plant as a whole and to determine the ratio at which the reproductive phase sets in. The C/N ratio of the leaves, stem and reproductive parts under four treatments is given in Table III, and of the whole plant in Table IV. As there appeared to be no differences between the treatments the means of the four treatments can be taken for study.

There was a continuous fall in the C/N ratios of the leaves from 1st August till the crop came into flowering phase. It dropped to 0·522 on 16th October after which there was rise. This fall and rise in the C/N ratio appeared to be related to the fall and rise in the total carbohydrates of the leaves as the changes in the nitrogen content were of much smaller magnitude during this period. The lowest value of C/N ratio on 16th October in the leaves was due to the fall in carbohydrate contents on that date and that was accompanied by the lowest percentage increase in dry matter. It was also a stage when the reproductive parts contained largest quantities of carbohydrates. Nearly 60 per cent of the total carbohydrates present in the plant were found in the reproductive parts, while the leaves contained only 10 per cent of the total carbohydrates. Thus low C/N ratio of the leaves appeared to be the result of the rapid utilisation of carbohydrate food for purposes of growth when the seasonal conditions became favourable while no such fall was noticed in the total nitrogen content.

The later rise in C/N ratio can be related to the rise in the carbohydrate contents of the leaves. Thus the fall and rise of the carbohydrate/nitrogen was an indication of the relative utilisation or accumulation of the carbohydrates in the leaves.

The trends in the C/N ratios of the stem were similar to those of the leaves except that there was a rise in carbohydrate/nitrogen ratio on the 16th August and the 1st September indicating storage of carbohydrate in the stem. C/N ratio was as high as 7·76 on 1st September. It began to fall after that date, and was lowest on 16th October indicating the stems like the leaves were depleted of their carbohydrates. There was a remarkable rise in C/N ratio on the 1st November. It was pointed out earlier that in this fortnight there was high photosynthetic activity which produced larger amount of carbohydrates. C/N ratio of the stem remained very high on account of accumulation of starch and low nitrogen content of the stem.

The C/N ratio of the reproductive parts was high in the beginning (excepting TIBA treated plants) due to a high carbohydrate content. It was very high on

16th October when C/N ratios of leaves and stems were lowest. Thus, there was a preponderance of carbohydrates which were utilised in flower and fruit formation. At the end of the season the C/N ratio became low as most of the carbohydrates were converted into fruiting parts and oil in the seed.

The C/N ratio of the whole plant at each fortnightly stage was calculated from the total carbohydrate and total nitrogen calculated per plant. The C/N ratio was high on the 1st August. It is possible that higher amounts of carbohydrates were derived from the seed due to conversion of oil. The C/N ratio was lowest on 1st October after which the value fluctuated within narrow limits.

Too much importance on the relation of C/N ratio with the setting in of the reproductive phase has been attached by various workers ever since Kraus and Kraybill first drew the attention to this important relationship. It is not the main purpose of this investigation to study this relationship but as carbohydrate and nitrogen analyses of the cotton plant were made, it was considered worthwhile to examine it. There was a drop in the C/N ratio of the leaves when the plant came into flowering activity and it dropped further on the 16th October when the bolls began to mature. This drop in C/N ratio was caused by the utilisation of carbohydrates for growth. C/N ratio of the leaf was about 1·5 on the 16th September but that was not the case with the stem where it was as high as 4·5 because transfer of carbohydrates occur from the leaves *via* the stem. C/N ratio of the whole plant was 2·58 on the 16th October and 1·55 on the 1st October. Thus, it is difficult to say which is the cause and which is the effect. It appears that rapid transfer and more rapid utilisation of carbohydrates in the formation of fruiting parts brought about the lowering of C/N ratio at the setting in of the reproductive phase.

TABLE III

Carbohydrate/nitrogen ratios

Date	Control	TIBA	NAA	IBA	Mean
Leaf					
1st August	3·59	3·54	3·82	3·73	3·66
16th August	1·72	1·75	1·35	1·90	1·68
1st September	1·79	1·28	1·07	1·23	1·34
16th September	1·99	1·40	1·33	1·70	1·60
1st October	1·08	1·03	1·34	1·42	1·21

TABLE III—*contd.*

Carbohydrate/nitrogen ratios—contd.

Date	Control	TIBA	NAA	IBA	Mean
Leaf—contd.					
16th October	0·522	0·341	0·585	0·316	0·441
1st November	0·977	1·55	1·26	1·17	1·23
16th November	1·48	2·01	2·39	2·87	2·18
1st December	2·38	1·71	1·15	1·29	1·63
16th December	2·39	2·14	2·26	2·29	1·27
Stem					
1st August	5·25	5·32	5·36	5·28	3·02
16th August	7·68	8·62	6·53	10·57	8·35
1st September	7·76	7·73	4·25	6·57	6·57
16th September	4·57	5·91	4·77	4·65	4·72
1st October	3·00	1·62	1·86	2·14	2·15
16th October	2·04	1·47	1·82	2·21	1·88
1st November	7·40	8·73	8·38	7·51	8·00
16th November	3·66	4·31	1·24	1·64	2·71
1st December	4·56	4·40	3·96	2·89	3·95
16th December	4·21	6·33	6·65	4·49	5·42
Flowering Parts					
16th September	3·38	1·98	3·58	2·60	2·88
1st October	3·04	2·45	2·45	2·33	2·56
16th October	3·86	4·49	2·87	3·97	3·79
1st November	1·82	1·66	1·71	1·85	1·76
16th November	1·67	1·80	2·52	2·43	4·10
1st December	1·68	1·66	1·78	1·45	1·64
16th December	0·70	0·645	0·733	0·779	0·714

TABLE IV

Carbohydrate/nitrogen ratio per plant

Date	Control	TIBA	NAA	IBA	Mean
1st August	3·89	3·87	4·03	4·01	3·95
16th August	2·42	2·54	2·01	3·19	2·54
1st September	2·61	2·07	1·50	2·01	2·04
16th September	2·58	1·96	1·95	2·17	2·16
1st October	1·55	1·42	1·59	1·69	1·56
16th October	2·11	1·96	1·45	1·40	1·73
1st November	2·09	2·62	2·17	2·20	2·27
16th November	1·84	2·21	2·36	2·55	2·24
1st December	2·18	1·80	1·78	2·05	1·95
16th December	1·51	1·38	1·75	1·54	1·54

CONCLUSIONS

The carbohydrate analysis of the different parts of the cotton plant (*G. hirsutum*) at fortnightly intervals brought out clearly the fact that starch was the main carbohydrate present, while hexose and cane sugars were found in much smaller amounts at all stages. The starch content fluctuated in the leaf from 0·2 per cent to 8 per cent on the dry weight basis of the leaves. The hexoses and cane sugar varied. Starch was thus the main carbohydrate stored up in the leaves.

The analysis of the stem indicated similar distribution of different carbohydrates. Starch content of the stem was as high as 5 per cent at some stage and as low as 0·5 per cent at another stage. The hexose sugars were present in small amounts while the quantities of the cane sugar were found to be in larger amounts than those found in the leaves.

The reproductive parts during the early stages of development contained largest amounts of starch but it dropped rapidly becoming about nil at the end of the season. It indicated that there was great mobilisation of starch in the flowering parts it being utilised after conversion for the development of bolls. It is possible some carbohydrates were lost when the buds, flowers or bolls were shed. The concentration of sugars in the reproductive parts fluctuated within narrow limits indicating their continued formation and utilisation in the processes leading to the development of bolls. At maturity some sugars were still present and their presence was also likely in the carpels.

The study of the periodic changes in the different carbohydrate contents of the leaves, stems and reproductive parts indicated few interesting features. A high sugar and starch content in the leaves in early stages of growth followed by a sharp fall in the first fortnight of August was a common feature. When the weather conditions became bright in September, a rise in carbohydrate contents of leaves was visible indicating increased photosynthetic activity. This was also the stage when flowering phase set in. After that stage (16th September), a big drop in the starch content was visible showing its rapid utilisation in the flowering parts. Thus on 16th October when buds and flowers were present in largest numbers, the leaves were completely depleted of their main carbohydrate storage. The starch content of the stem was also at the lowest level, while the reproductive parts showed the highest amount of starch. This was also the stage when the increase in dry matter was the least. As photosynthetic activities increased on account of the return ot the brighter weather, an increase in starch content was again noticed after this stage. Thus, there was a temporary drain of carbohydrates during the active phase of the flowering and the setting of bolls and the shedding of buds, flowers and bolls would very probably be governed by the carbohydrate status of the plant at that stage. It was at this stage that the C/N ratio of the leaves and stems reached its lowest values on account of a big drop in the carbohydrate contents. On 16th October the C/N ratio of the leaf was 0·50, of the stem 2·0 and of the plant as a whole 2·0. The C/N ratio of the reproductive parts alone was as high as 3·86. These figures clearly indicated the movement of carbohydrates from the leaves and stem to the reproductive parts.

At the end of the season starch content of the leaves was nearly 2·8 per cent while that of the stem 1·8 per cent indicating the unutilised starch. Thus the efficiency for the utilisation of starch by the cotton plant was low and this may be due to a decrease in nitrogen content, found at that stage. The total nitrogen in the leaves at the end of the season was 1·7 per cent out of which 1·4 per cent was in the form of protein nitrogen in the control plants. Thus there was hardly any nitrogen present in an inorganic form for the formation of aminoacids and their conversion into proteins. This is the condition as it exists under natural conditions in the field. What would be the state of affairs if extra nitrogen was supplied as was done by Eaton and Rigler [1945] ? Will it bring about further utilisation of carbohydrates if nitrate or ammoniacal nitrogen is supplied, just before the termination of metabolic activity ?

It will be seen that C/N ratio indicated only the relative utilisation of the carbohydrates at different stages of growth and their conversion into cellulose or proteins while total nitrogen represented all forms of nitrogen. The percentage decrease in total nitrogen was indicative of greater increase in dry matter which was not compensated by increased absorption from the soil. Thus low C/N ratio at the flowering stage indicated only the rapid utilisation of carbohydrate for the formation of reproductive parts.

The effect of chemical hormones on the carbohydrate production of the cotton plant cannot be found out by carbohydrate analysis only as the carbohydrates

manufactured by the plants did not remain as such. There was firstly continuous conversion of one form of carbohydrate into another and they were continually being utilised in the development of the different parts of the plant body. Thus total carbohydrate contents of the plants treated with the three chemical hormones and of the untreated plants may not indicate any effect of these treatments even though hormone treatment had actually stimulated photosynthetic activity. It would not be revealed by mere carbohydrate analysis. The only criteria for judging these effects would be the determination of dry weight of the plants especially of the leaves and reproductive parts. In spite of these limitations carbohydrate analysis had given some indications of enhancing the effects on carbohydrate production by their greater accumulation in the leaves and in the flowering parts at a stage when the plants were found to be in the most active stage of growth, i.e. in November. There was a greater accumulation of cane sugar and starch in the leaves of hormone treated plants on 1st November. It was also a stage when plants under all treatments added the largest percentage of total dry matter (Fig. 25). The stem also showed a greater accumulation of hexose and cane sugar at that stage, indicating rapid transfer from the leaves to the stem and ultimately to the reproductive parts.

The real effect of hormone treatment was visible on the dry matter per plant. The weight per plant treated with hormones became significantly higher than the dry weight per plant in the control from 1st November (Fig. 17), and it was significantly higher at each stage afterwards up to the last date of sampling, i.e. 16th December (Table I). Thus there was a positive evidence of the effects produced by these hormones on the carbohydrate metabolism of the plant.

The increase in dry weight of the plant in the hormone treated series was mainly due to the increase in the dry weight of the reproductive parts. The differences in the dry weights of the reproductive parts were statistically significant from 1st November (Table II). When the results of the dry weights of the reproductive parts were calculated per 100 gm. of total dry weight of the plant, it was found that treated plants produced more of reproductive parts than the control plants. This leads to the conclusion that the efficiency of the plant for fruiting was increased by these hormone applications under field conditions.

It is not definite which of the three hormones produced the greatest effect on the carbohydrate metabolism of the plant but both TIBA and NAA produced the largest dry weight per plant.

Though the hormones were sprayed on the plants on 8th August, the effects of these applications on the dry weights as well as on the carbohydrate contents were not visible until 1st November, i.e. nearly three months after application.

The nitrogen analysis of the plant showed some interesting features. Though there was no effect of hormones on the total nitrogen of the leaves and stem, the reproductive parts of the treated plants from the very beginning of their formation showed consistently higher nitrogen content than the reproductive parts of the control plants. Thus both reducing sugars and nitrogen were available for reproductive growth in larger concentrations than in the controls. Similarly the

results of protein analysis indicated that larger amounts of proteins were synthesised in the treated plants.

The study of the percentage distribution of total carbohydrate in each part of the plant revealed some interesting facts and explained the sudden fall in starch content and cane sugar content on 1st October. The demand for carbohydrates at this stage was so great that the leaves and stem became depleted of the carbohydrate food. Thus it was a period when the demand for carbohydrates was the greatest. This conclusion can be supported by Table V where the percentage distribution of the total carbohydrates in the three parts of the cotton plant viz. leaves, stem and reproductive parts, is given.

TABLE V

Percentage distribution of total carbohydrates

Date	Leaves	Stem	Reproductive Parts
1st August	77·92	22·07	..
16th August	65·32	34·67	..
1st September	59·93	40·07	..
16th September	56·76	28·60	14·84
1st October	53·88	20·37	25·73
16th October	11·51	9·83	78·65
1st November	24·55	45·05	30·39
16th November	35·00	24·56	40·35
1st December	32·56	20·28	47·15
16th December	37·79	32·02	30·18

In the leaves there was 77·92 per cent of total carbohydrates on the 1st August and it declined from that date to about 11·5 per cent of the total on 16th October. In the stem there was a rise in the percentage of total carbohydrates from 1st August to 1st September. It increased in the stem from 22 per cent to 40 per cent of the total due to translocation from the leaves but after 1st September there was a steep fall and it reached a level of 9·83 per cent. From 16th September when flowering phase set in, a marked and rapid rise in the total carbohydrates was visible in the reproductive parts. It rose from 14·8 per cent on the 16th September to 78·6 per cent on the 16th October. That was the date when the leaves and stems were nearly depleted of their carbohydrates. Thus it was clear that the flow of carbohydrates in the stems and leaves brought about the lowering of the C/N ratio.

SUMMARY

The periodic changes in different carbohydrate contents of the leaves, stem and reproductive parts of the cotton plant (*G. hirsutum*, Indorel) grown under the rainfed conditions in the field are studied and the effect of three chemical hormones, viz. 2-3-5-triiodobenzoic acid, α-naphthalene acetic acid and α-3 indolyl butyric acid on the carbohydrate contents of the different parts of the plant and on their dry weights are investigated. Starch was the main carbohydrate found in all the parts of the cotton plant.

A sharp fall in carbohydrates in the first fortnight of August, a rise in September when the weather conditions became favourable, was a feature of the leaves. Both leaves and stem became nearly depleted of their carbohydrates in the first half of October. This was the stage when the carbohydrate contents of the reproductive parts were the highest on account of the production of buds, flowers and bolls. Eighty per cent of the total carbohydrates found in the plant were present in the reproductive parts at that stage.

The starch content of the leaves and stems showed a rise after the 16th October and at the end of the season a fair amount of carbohydrates remained unutilised in the leaves and stem.

Though metabolic carbohydrates underwent continuous transformation into cellulose as the plant grew, the effect of hormones on the carbohydrate production was visible on the 1st November when the hormone treated plants showed greater carbohydrate accumulation in leaves and stem and reproductive parts.

The effect of hormones was most visible on the production of dry matter per plant. The total dry weights of hormone treated plants were significantly greater than the total dry weight of the control plants from 1st November onwards upto the end of the season. The higher dry weight of the treated plants was mainly due to the higher dry weights of the reproductive parts. It was thus found that the applications of hormones increased the efficiency of the cotton plant for fruit production.

Though the cotton plants were sprayed on 6th August, the effect on carbohydrate and dry weights became visible on 1st November. There was no effect of hormone application on the total nitrogen of the stem and leaves, but the reproductive parts showed greater nitrogen content like hexoses at all stages. The protein nitrogen of the leaves, stem and reproductive parts was also higher in the treated plants than in the control.

It is suggested that non-utilisation of carbohydrates from the leaves and stem found at the end of the season may be due to decrease in nitrogen contents.

Study of the C/N ratios of the leaves, stem and reproductive parts and the whole plant indicated that fall and rise in C/N ratios was related to the fall and rise in the carbohydrate contents. Greater depletion of carbohydrates in the first half of October brought about a great fall in C/N ratio. It is not at all clear whether a fall in C/N ratio was related to the initiation of the reproductive phase.

REFERENCES

Brown, C. A. (1947). The Effects of 2-4-D on Cotton. *Amer. J. Bot.* ***34***, 20. a

Caskey, C. Jr. and Gallup, W. D. (1931). Changes in the Sugar, Oil, and Gossypol content of the Developing Cotton Boll. *J. agric. Res.* ***42***, 671-674

Dastur, R. H. and Ahad, A. (1944). Studies in the Periodic Partial Failures of the Punjab-American Cottons in the Punjab. XI Trends in Growth of Normal and Tirak Plants with Special Studies on Bolls. *Indian J. agric. Sci.* ***14***, 152-160

——(1945). Studies in the Periodic Partial Failures of the Punjab-American Cottons in the Punjab. XV Formation of Proteins, Oil and Cellulose in the Bolls of Normal and Tirak Affected Plants. *Indian J. agric. Sci.* ***15***, 75-85

—— and Samant, K. M. (1933). A Method for the Determination of Carbohydrates in Leaves. *Indian J. agric. Sci.* ***3***, 460-477

—— and Ved Prakash (1954). Responses of the Cotton Plant to some Growth Regulating Substances. *Indian Cotton Grow. Rev.*

Dunlap, A. A. (1948). 2-4-D injury to cotton from Airplane Dusting of Rice. *Phytopat.*, ***38***, 631-644

—— (1937). Determination of Total Nitrogen Using Selenium. *J. Industr. & Eng. Chem.*

Eaton, F. M. and Ergle, D. R. (1947). Carbohydrate Accumulation in the Cotton Plant at Low Moisture levels. *Plant Physiol.* ***22***, 377-392

—— and Joham, H. E. (1944). Sugar Movement to the Roots, Mineral uptake and the Growth Cycle of the Cotton Plant. *Plant Physiol.* ***19***, 506-517

—— and Rigler, N. E. (1945). Effect of light Intensity, Nitrogen Supply and Fruiting on Carbohydrate Utilisation by the Cotton Plant. *Plant Physiol.* ***20***, 380-410

Ergle, D. R. (1936). Carbohydrates of the Cotton Plants at Different Growth Periods and the Influence of Fertilisers. *J. Amer. Soc. Agron.* ***28***, 775-785

—— and Hesseler, L. E. & Adams, J. E. (1938). Carbohydrates of the Cotton Plant under Different Seasonal conditions and Fertiliser Treatment. *J. Amer. Soc. Agron.* ***30***, 951-959

—— and Eaton, F. M. (1951). Sulphur Nutrition of Cotton. *Plant Physiol.* ***26***, 638-654

—— and Dunlap, A. A. (1949). Responses of Cotton to 2-4-D. *Texas Agric. Exp. Sta. Bull.* ***713***

Erickson, L. C., Siely, C. I. and Clapes, K. H. (1948). Effects of 2-4-D upon the Protein Contents of Wheats. *J. Amer. Soc. Agron.* ***40***, 659-660

Greulach V. A. and Sucha Singh (1949). Effects of Naphthalene Acetic Acid and Naphthalane, Acetimide on the Development of the Cotton Plant. *Amer. J. Bot.* ***36***, 646-651

Mason, T. G. and Maskell, E. J. (1928). Studies on the Transport of Carbohydrates in the Cotton Plant. I. A Study of Diurnal Variations in the Leaf, Bark, and Wood, and of the Effects of Ringing. *Annals Bot.* ***42***, 189-253

Maskell, E. J. and Mason, T. G. (1930). Studies on the Transport of Nitrogenous Substances in the Cotton Plant. V. Movement to the Boll. *Annals Bot.* ***44***, 637-677

Mcllarth, W. G. (1950). Response of the Cotton Plant to Maleichydrazids. *Amer. Jr. Bot.* ***37***, 816-819

Mitchell, J. W. and Brown, J. W. (1945). Effect of 2-4-D on the Readily Available Carbohydrate Constituents in Annual Morning Glory. *Bot. Gaz.* ***107***, 120-129

—— and Stuart, N. W. (1938-39). Growth in metabolism of Bean Cuttings Subsequent to Rooting with Indole Acetic Acid. *Bot. Gaz.* ***100***, 627-550

Methods of Analysis, (1935). *Assocn. Officl. Agric. Chems.*

Rakitin, Y. V. and Ovcharov, K. E. (1948). Cotton Plant: Growth and Productivity: Effect of Adenine and Nicotinic Acid. *C. A. Acad. Sci. U.S.S.R.* ***61***, 938

Resmussen, L. W. (1947). The Physiological Action of 2-4-D on Dendelion, Taraxacum Officinale. *Plant Physiol.* ***22,*** 377-392

Sell, H. M., Lucke, R. W. Taylor, B. M. and Hamner, C. L. (1949). Changes in Chemical Composition of Red Kidney Bean Plants Treated with 2-4-D. *Plant Physiol.* ***24,*** 295-299,

Somogyi, M. (1945). A Micro-method for the Determination of Reducing Sugar. *J. Biol. Chem.* ***61,*** 160

Shriner, R. L. (1932). Determination of Starch in Plant Tissues. *Plant Physiol.* ***7,*** 541-546

Staten G. (1946). Contamination of Cotton Fields by 2-4-D or Hormone Type Weed Sprays. *J. Amer Soc. Agron.* ***38,*** 536-544

Stuart, N. W. (1938). Nitrogen and Carbohydrate Metabolism of Kidney Bean Cuttings as Affected by Treatment with Indole Acetic Acid. *Bot. Gaz.* ***100,*** 198-212

Wost. D. J. (1949). Response of Buck Wheat to Treatment with 2-4-D. *Amer. J. Bot.* ***36,*** 673-675

Zimmerman, P. W. and Willcoxen, F. (1935). Several Chemical Growth Substances which Cause Initiation of Roots and Other Responses in Plants. *Contro. Boyce Thompson Inst.* 209-229

SOILS OF THE ANDAMAN ISLANDS*

By R. V. Tamhane, K. V. Satyanarayana and Abhiswar Sen, Indian Agricultural Research Institute, New Delhi

(Received for publication on June 13th 1954)

The area of the Andamans is 2,508 square miles and of Nicobar 635—totalling 3143 square miles. The Great Andamans contain a large number of hills with steep valleys mostly covered with dense tropical jungle developed under a fairly heavy rainfall varying from 76 to 124 inches, warm temperature[1] and high humidity.[2]

The total cleared area in the Andamans is about 182,000 acres, of which 5,600 acres are under paddy cultivation and 300 acres under gardens. About 2,500 acres are under cocoanut.

Steep hill slopes with a number of creeks extending over a very long coast-line and heavy rainfall provide best conditions for soil erosion in spite of rich forests. For the development of an efficient agricultural system in the islands, which have gained much importance in view of the refugee rehabilitation problem, it is essential to develop practices which will reduce the natural erosion to the minimum.

It is also necessary that the characteristics of the soil are known well for better land use in the islands. During the present investigation, soils from different islands were analysed for various constituents with the object of gaining information regarding the nature of the soils and the deficiencies, if any, existing or any particular nutrient required for good crop growth.

Material

Soils

The soil profiles were collected from virgin forest lands at different localities in the Andaman islands. Each profile was taken from the soil up to a depth of 3 ft. and in general, each sample represented soil of 1 ft. depth. A description of the profiles is given below :

Middle Andamans : The area of Middle Andaman is covered with magnificient forests. There is little sign of erosion under forest cover. The hill sides show terraced effect produced by lateral roots of the forest trees and a great deal of root exposure. The soil in the north is red sticky clay ; and in the valley brown sandy clay. The soil is well drained and many areas covered with loose sandstones show signs of loss of soil.

* Paper read at the 41st Session of the Indian Science Congress : Abstract published in the proceedings of the same

[1] Mean daily minimum temperature—67°F
Mean daily maximum temperature—99°F

[2] Average humidity—83 per cent

Profile I : Bajlendra creek, Perloh Jig, on the valley, vegetation [illegible] type

0—1 ft.
1—2 ft. Grey brown clay from the surface to the third foot dept[illegible]
2—3 ft. with loose stones ; much surface run off ; soils gave a[illegible]

Profile II : Bajlendra creek, Perloh Jig, on the hill side, evergree[illegible]

0—1 ft.
1—2 ft. Brown sandy clay throughout, good permeability, sl[illegible]
2—3 ft.

Profile III : Seaward Bay, 2½ miles from Bomington

0—1 ft.
1—2 ft. Red brown fine clay, turning darker at third foot de[illegible]
2—3 ft. acid

North Andamans : Island formed of conglomerates with sandstone [illegible]
Soil is dark clay and extremely sticky

Profile IV : North of Port Cornwallis

0—1 ft. First two feet light brown fine clay with one inc[illegible]
1—2 ft. humus layer on top ; third foot grey clay with [illegible]
2—3 ft. sandstone seams ; surface soil slightly acid, aci[illegible] with depth.

Rutland Island : In southern most Andaman, the soils consist of [illegible] (i) coarse sandy loam of red colour, (ii) grey clay and (iii) red clayey loa[illegible] is heavily forested. There are root exposures on hill sides which are [illegible] loose sandstones.

Profile V

0—1 ft. Red clayey loam ; solid seams of red sandstone [illegible]
1—2 ft. acid reaction

[illegible] Island : This island comprising Middle Andaman strait [illegible] strait is heavily forested with large trees of deciduous types [illegible]. The soils have good drainage.

Profile VI : Rafters' creek, south Baratang

0—1 ft.
1—2 ft. Red clay throughout with very fine sand, [illegible]
2—3 ft.

Profile [illegible]II : Luru Zig, Middle Baratang

[illegible]
2—3ft. } Grey clay throughout, surface runoff evident, acid

Profile [illegible]III : Oriel Kaicha, West Baratang

0—1ft.
1—2ft.
2—3ft. } Red clay, soils acid throughout

[illegible] archipelago : This group of low lying islands, off the east coast of Middle and [illegible] Andaman is covered with thick forest; the soil is chiefly composed of sand[illegible] and grey clay with limestone and conglomerates. The soil varies from stiff grey clay to permeable red clayey loams on the sandstones.

Profile X : John Lawrence Island

[illegible]
[illegible]
2—3ft. } Black loamy clay turning to dark grey clay at second foot depth; soils slightly acid

Profile X[illegible] : Henry Lawrence Island

0—1ft.
[illegible]
2—3ft. } Dark brown loamy clay turning to red brown at second foot; soil slightly acid

Profile XI : Havelock Island

0—1ft.
[illegible]
2—3ft. } Grey clay with a few inches of black grey humus at the surface; soils acid throughout.

Methods

T[illegible]ods of analysis followed were the same as given in A. O. A. C. [1950].

[illegible]e P_2O_5 and K_2O in the soils were determined by Dyer's 1 per cent citric acid extraction method.

[illegible]es of the soils were determined by Glass Electrode [Piper 1942].

Results

[illegible] of determination of pH mechanical composition and chemical composition of the clays extracted from the soils are given in Table I.

TABLE I

pH, mechanical composition of the soils and the composition of clays
(Results expressed as per cent on oven dry basis)

Locality	Depth in ft.	pH	Mechanical composition				Composition of clay	
			Coarse sand	Fine sand	Silt	Clay	SiO_2/Al_2O_3	SiO_2/R_2O_3
Bajlendra Creek	0—1	5·20	8·36	22·46	16·56	44·44	2·39	2·78
	1—2	4·90	1·41	10·38	16·32	59·08	2·83	3·44
Campsite	2—3	6·40	1·11	9·93	23·60	61·12	2·95	3·59
Bajlendra Creek	0—1	5·70	0·86	54·41	18·00	23·60	2·06	2·62
	1—2	5·00	2·91	39·94	23·68	32·72	2·07	2·66
Hillside	2—3	5·00	0·49	40·16	22·40	35·20	2·06	2·68
Seaward Bay	0—1	6·30	0·55	8·32	14·40	68·40	2·66	3·12
	1—2	5·30	0·44	6·60	10·32	72·40	2·81	3·42
	2—3	5·90	0·62	6·72	14·52	71·08	2·52	3·05
Port Cornwallis	0—1	5·20	6·33	25·21	18·60	41·60	2·60	3·26
	1—2	5·40	3·55	20·00	20·80	50·00	2·49	2·98
	2—3	7·60	16·13	35·33	11·00	26·60	2.51	3·08
Rutland Island	0—1	5·20	1·09	56·00	11·80	25·60	1·87	2·38
	1—2	4·90	6·74	48·46	20·80	17·60	1·69	2·10
Ratter's Creek	0—1	5·80	0·30	48·73	9·20	35·60	2·73	3·42
	1—2	4·90	0·15	37·17	11·20	44·00	2·72	3·37
	2—3	5·24	9·60	32·06	17·00	35·20	2·96	3·59
Luru Zig	0—1	5·13	31·89	21·73	16·60	26·60	2·27	2·87
	1—2	5·47	21·85	17·06	22·68	35·32	2·31	2·85
	2—3	6·82	17·39	16·77	16·88	45·32	2·20	2·74
Oriel Kaicha	0—1	4·66	38·10	10·84	10·48	32·00	2·15	2·70
	1—2	4·49	19·37	10·43	12·40	53·20	1·92	2·43
	2—3	4·57	20·09	8·23	14·88	51·72	1·85	2·34
John Lawrence Island	0—1	6·18	9·58	17·51	22·20	44·80	2·52	3·15
	1—2	6·62	15·64	14·56	22·72	41·28	2·46	3·07
	2—3	6·82	8·66	14·12	26·68	45·72	2·52	3·03
Henry Lawrence Island	0—1	5·89	13·31	42·37	5·52	35·88	1·85	2·65
	1—2	5·64	10·43	23·47	7·52	54·48	1·74	2·51
	2—3	6·06	7·00	20·67	8·40	58·40	1·79	2·66
Havelock Island	0—1	5·20	34·14	11·35	12·08	35·20	2·80	3·68
	1—2	5·00	11·85	5·40	12·20	64·40	2·87	3·71
	2—3	5·08	22·59	9·28	14·24	48·40	2·80	3·63

Table II shows the organic carbon, organic nitrogen, C/N ratios, CaO, total and available K_2O and P_2O_5 contents of the soils.

TABLE II

Organic carbon, nitrogen, CaO and total and available K_2O and P_2O_5 contents of the soils

(Results expressed as per cent on oven dry basis)

Locality	Depth in ft.	Organic carbon	Organic nitrogen	C/N	CaO	Total		Available	
						P_2O_5	K_2O	P_2O_5	K_2O
Bajlendra creek	0—1	0·55	0·109	5·09	0·24	0·038	0·63	0·0009	0·0234
	1—2	0·31	0·052	5·87	0·57	0·108	0·74	0·0168	0·0340
Campsite	2—3	0·27	0·052	5·14	0·67	0·047	0·64	0·0052	0·0152
Bajlendra creek	0—1	0·48	0·080	5·94	0·09	0·063	0·44	0·0036	0·0211
	1—2	0·34	0·072	4·74	0·08	0·066	0·38	0·0025	0·0146
Hillside	2—3	0·30	0·018	3·75	0·06	0·059	0·58	0·0021	0·0247
Seaward Bay	0—1	1·50	0·176	8·55	0·93	0·054	0·68	0·0017	0·0334
	1—2	0·48	0·054	8·98	0·76	0·025	0·47	0·0013	0·0169
	2—3	0·45	0·104	4·37	0·95	0·030	1·09	0·0009	0·0202
Port Cornwallis	0—1	0·71	0·056	12·54	0·12	0·056	0·67	0·0021	0·0189
	1—2	0·27	0·045	6·04	0·12	0·032	0·76	0·0011	0·0187
	2—3	0·19	0·040	4·78	0·15	0·065	0·46	0·0049	0·0207
Rutland Island	0—1	1·26	0·155	8·13	0·03	0·051	0·35	0·0011	0·0450
	1—2	0·22	0·041	5·19	0·01	0·067	0·26	0·0001	0·0163
Rafter's Creek	0—1	1·30	0·169	7·69	0·60	0·073	0·45	0·0048	0·0337
	1—2	0·66	0·101	6·54	0·73	0·055	0·56	0·0027	0·0186
	2—3	0·50	0·071	7·00	—	0·043	0·30	0·0030	0·0200
Luru Zig	0—1	1·19	0·135	8·80	—	0·043	0·53	0·0016	0·0110
	1—2	0·42	0·066	6·38	—	0·027	0·70	0·0012	0·0102
	2—3	0·43	0·066	6·53	—	0·073	0·77	0·0140	0·0117
Oriel Kalcha	0—1	0·99	0·128	7·73	—	0·042	0·30	0·0015	0·0197
	1—2	0·67	0·101	6·68	—	0·035	0·49	0·0009	0·0075
	2—3	0·51	0·085	6·06	—	0·053	0·29	0·0006	0·0048
John Lawrence Island	0—1	1·87	0·251	7·45	—	0·061	0·30	0·0045	0·0252
	1—2	0·94	0·146	6·43	—	0·032	0·23	0·0029	0·0173
	2—3	0·83	0·131	6·34	—	0·023	0·24	0·0026	0·0146
Henry Lawrence Island	0—1	1·07	0·155	6·91	—	0·106	0·26	0·0020	0·0156
	1—2	0·51	0·072	7·02	—	0·115	0·39	0·0011	0·0150
	2—3	0·57	0·079	7·22	—	0·166	0·46	0·0014	0·0070
Havelock Island	0—1	1·34	0·154	8·70	—	0·070	0·31	0·0070	0·0175
	1—2	0·50	0·063	7·89	—	0·037	0·29	0·0026	0·0084
	2—3	0·28	0·043	6·48	—	0·020	0·25	0·0011	0·0156

DISCUSSION

In the Middle Andaman there is an increase in content of clay with depth in all the three profiles from the three different sites. Lowest content of clay is observed in the soils of the hillside profile. The clay content of soils of the profile in the valley is somewhat higher ; highest content of clay is observed in the Seaward Bay profile. This shows loss of clay with water from higher level on the hillside to lower one in the valley. The largest accumulation of clay has occurred in the bay. From the silica-alumina and silica-sesquioxide ratios which are lowest in the hillside soil profile, it is also observed that apart from extensive loss of clay, there is extensive leaching. This is also seen by the lowest contents of CaO and K_2O in the soils of the hillside profile ; the bases are somewhat higher in the soil profile from the valley ; they are highest in the soils of the profile from the bay. Carbon and nitrogen contents at the surface at least, follow the same order, all pointing to the movement of soil from the hillsides to the valley below and probably from the valley to the sea side by the river or run off water during heavy rains. In the profile on the Seaward Bay, there is a sudden increase in the nitrogen content at the third foot. This may be due to (1) movement of organic matter down the profile as in the case of podsols or (2) due to deposition of fresh soil over an old soil surface. From other characteristics the possibilities of podsolisation may be ruled out. Burying down of an old soil by fresh deposits presenting a new soil surface seems to have taken place in this area.

The soils at Port Cornwallis in the North Andaman are similar to the soils of the valley in the Middle Andaman. Unlike the former, however, the clay content decreased at the third foot depth where the soil is also somewhat alkaline. The soil is poorer in lime than the soil of the valley in the Middle Andaman.

From the silica-alumina and the silica-sesquioxide ratios of the clay and lower content of bases like lime and potash, the soil of the Rutland Island shows a greater degree of leaching than the soils of the Middle Andaman or the North Andaman.

The silica-alumina and silica-sesquioxide ratios of the clay indicate that leaching is less pronounced in the soil in the southern part of the Baratang Island than in the Middle or West Baratang. This is also shown by presence of some lime in the soil of South Baratang and absence of the same in the Middle or West. The clay content in the soil in the South Baratang does not show any definite tendency to increase or decrease with depth while in the Middle or West Baratang the clay content increases with depth, more regularly so in the Middle Baratang.

The variation with depth in the clay content of the soils at John Lawrence and Havelock Islands is somewhat irregular, though very little in the former as compared with the latter. The soil of the John Lawrence is also less acid than that in Henry Lawrence and Havelock Islands. From the silica-alumina and silica-sesquioxide ratios of clays it is seen that leaching is far greater in the soils of the Henry Lawrence Island than in the other two. Lime is absent in all the three Islands. The soils also contain the lowest amount of potash as compared with the soils of the other islands of the Andaman group.

In general, it can be observed that soils of the different parts of the Andaman Islands contain fairly high amount of clay and are of silty clay to loam in nature. The *p*H is mostly on the acid side. The lime status is low and free $CaCO_3$ is absent. The soils contain fairly high amounts of nitrogen. The C/N ratios of the soils are generally below 10. Highest content of nitrogen and organic matter is observed at the surface. The total P_2O_5 contents are low in many cases and even in soils where total P_2O_5 appears to be sufficient, available P_2O_5 is low. The silica-alumina and silica-sesquioxide ratios of the clay indicate that the soils have undergone considerable leaching. Drainage conditions appear to be fair inspite of the high clay contents of tne soils. For successful cultivation of crops the soils appear to need liming and treatment with phosphatic fertilisers like bonemeal or basic slag.

Summary

Soil samples were collected from three places in the Middle Andaman, one in the North Andaman, one in the Rutland Island, three places in the Baratang Island and from three islands belonging to Ritchies' archipelago. Samples were taken up to three feet depth from each locality and each sample was drawn at one foot depth from each profile. The soils were analysed for mechanical composition, organic carbon, nitrogen, *p*H, CaO, total and available P_2O_5 and K_2O and SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios of the clays.

It has been observed that the soils contained fairly high amounts of clay and were of silty clay to clay loam in nature. The *p*H values were mostly on the acid side. The lime status was low and free $CaCO_3$ was absent. The soils on an average contained fairly high amounts of nitrogen and C/N ratios were generally below 10·0. The surface soils contained, most often, the highest amount of nitrogen and organic matter. The total P_2O_5 was low in many cases and even in soils where the total P_2O_5 appeared to be sufficient, the available P_2O_5 was invariably low. The SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratios of the clays indicated that the soils had undergone considerable acid type of leaching.

Acknowledgment

The authors' thanks are due to Mr. W. Vickers of the Lever Brothers (I) Ltd., for the supply of the samples of soil and their description, and to Messrs. K. B. Shome and D. P. Motiramani for help in the analytical work on the soils.

References

A.O.A.C. (1950). *Official Methods of Analysis*, VII edition, 29-46

Piper C. S. (1942). *Soil and Plant Analysis*, University of Adelaide, Adelaide

NITROGEN FIXATION BY ALGAL ASSOCIATIONS IN TANK SILTS

By ABHISWAR SEN, Indian Agricultural Research Institute, New Delhi

(Received for Publication on June 4, 1954)

DURING the course of a study of nitrification of tank silts in different types of soil, it was observed that, during a period of eight to ten weeks, in addition to nitrification, considerable fixation of nitrogen took place [Sen and Asija 1953, 1954]. Such fixation of nitrogen was not observed in untreated soils under the same conditions. To ascertain the factors responsible for fixation of nitrogen when nitrification was also active, a study of the nitrogen fixing flora of the tank silts was undertaken. It is well known that fixation of nitrogen by *Azotobacter* occurs at considerable expense of organic carbon and it was noticed that the carbon contents of the soil silt mixtures, during nitrification, did not decrease to such an extent as to account for these fixations of nitrogen by *Azotobacter*. It was thought possible that blue green algae reported to be capable of fixing nitrogen by themselves [Allison and Morris 1930 ; Allison and Hoover 1935 ; Allison, Hoover and Morris 1937 ; De 1939 ; Fogg 1942 ; Singh 1942] and in association with nitrogen fixing organisms like *Azotobacter* [Moore, Wheetley and Webster 1921 ; Allison and Morris 1930 ; Jones 1930] might be connected in some way with the fixation of nitrogen observed. Appearance of algae in soil during nitrification of nitrogenous fertilisers and manures has been observed by Mataprasad and Patwabardhan [1941]. The present report deals with studies on nitrogen fixation by mixed algal growths isolated from tank silts from 21 different places in West Bengal in (1) nitrogen-free inorganic medium in light without any internal supply of energy material for the growth of algae with thel microbial contaminants and in (2) a nitrogen-free medium in the dark with mannito as energy material encouraging the growth of the associated organisms only. No attempt was made to identify the individual alga contained in the mixed flora and to use pure monoalgal cultures for studies on nitrogen fixation and on nitrogen fixation by the associated organisms.

EXPERIMENTAL PROCEDURE

Isolation of the algae : Isolation of the algal flora was carried out by inoculating 100 c.c. of sterile Beuecke's medium (K_2HPO_4—0·5 gm ; $MgSO_4$—0·2 gm ; $CaSO_4$—0·1 gm ; $FePO_4$—1·0 gm ; $Ca_3(PO_4)2$—1·0 gm ; FeC_{13}, 1 per cent—two drops ; distilled water—1000 c.c.) kept in plugged flasks, with 1 gm. of air dry tank silt. The flasks were kept near a window. In about a month, algal growth appeared on the walls, on the surface and sometimes submerged on the silt beds at the bottom of the flasks. Scrapings from the walls of the flasks together with what could be collected from elsewhere by means of a preheated platinum needle were used in the nitrogen fixation studies.

Nitrogen fixation by algal growths: The algal scrapings were taken in a sterile test tube and washed with sterile water several times by decantation and introduction of a fresh lot of water. A loopful of the same was introduced into a sterilised flask containing 100 c.c. of Benecke's solution. For each tank silt, three such flasks were used. The flasks were kept near a window for two months after which the contents of each were treated with 30 c.c. of concentrated H_2SO when the algal filaments sticking to the sides of the flask were generally dissolved off. The algal material were then digested for the estimation of nitrogen by the Kjeldahl method.

Nitrogen fixation by the associated organisms: A loopful of the washed algal scrapings from the above experiment was introduced to 100 c.c. of sterile Ashby's solution (K_2HPO_4—0·2 gm; $MgSO_4$—0·2 gm; NaCl—0·2 gm; $CaSO_4$—0·1 gm; $CaCO_3$—1·0 gm; mannite—10·0 gm; distilled water 1000 c.c.) contained in plugged flasks which were kept, after inoculation, in the dark in an incubator at the room temperature. The inoculation was done in triplicates with algae from each of the ank silts. After incubation for two months, during which the introduced algal filaments appeared to have disintegrated or turned yellow or brown, the contents of each of the flasks were treated with 30 c.c. of concentrated H_2SO_4 and digested for the estimation of nitrogen by Kjeldahl method.

Presence of Azotobacter: A loopful of the surface material from Ashby's solution was plated on Asbhy's agar. An examination of the colour and of the cells showed that *Azotobacter* was the predominating organism.

Results

Amounts of nitrogen fixed in Benecke's and in Ashby's solutions and the growth of *Azotobacter* in Ashby's solution are indicated in Table I below.

Table I

Nitrogen fixed in Benecke's and in Ashby's solutions and the growth of Azotobacter *in Ashby's solutions*

Source	N(mg) fixed in 100 c.c. of Benecke's solution	N(mg) fixed in 100 c.c. of Ashby's solution	*Azotobacter* in Ashby's solution
Aurangabad (Dt. Murshidabad)	3·3 (2·7, 4·1, 3·0)	6·7 (5·8, 8·2, 6·2)	++
Beldanga (Dt. 24-Parganas)	2·6 (0·9, 1·5, 5·3)	3·0 (3·6, 2·9, 2·4)	+
Diamond Harbour (Dt. 24-Parganas)	1·7 (2·4, 1·1, 1·7)	5·0 (6·0, 4·0, 5·1)	++
Ghatal (Dt. Midnapur)	3·4 (3·9, 3·1, 3·2)	5·4 (4·6, 5·1, 6·6)	++
Ghorsala (Dt. Murshidabad)	2·6 (1·9, 1·6, 4·3)	1·4 (1·2, 1·5, 1·6)	—

TABLE I—*contd.*

Nitrogen fixed in Benecke's and in Ashby's solutions and the growth of Azotobacter *in Ashby's solution*

Source	N(mg) fixed in 100 c.c. of Benecke's solution	N(mg) fixed in 100 c.c. of Ashby's solution	*Azotobacter* in Ashby's solution..
Gidni (Dt. Midnapur)	3·3 (4·0, 1·8, 4·0)	3·0 (1·4, 4·6, 2·9)	+
Jangipur 532 (Dt. Murshidabad)	3·2 (2·3, 1·5, 5·3)	4·7 (5·8, 4·5, 3·6)	++
Jangipur 534 (Dt. Murshidabad)	3·1 (2·4, 2·8, 4·5)	2·2 (3·2, 1·4, 2·2)	±
Kalyanpur (Dt. 24-Parganas)	4·8 (5·4, 3·2, 5·9)	1·7 (2·1, 2·2, 0·9)	+
Khairagola (Dt. Birbhum)	3·1 (2·7, 1·0, 5·9)	2·6 (3·4, 1·8, 2·5)	—
Khirapai (Dt. Midnapur)	4·7 (6·4, 4·3, 3·5)	3·3 (4·1, 2·3, 3·2)	+
Khirasagar (Dt. Murshidabad)	3·0 (2·9, 4·3, 2·8)	3·1 (5·0, 1·2, 3·3)	+
Kulpi (Dt. Birbhum)	2·8 (3·0, 2·7, 2·8)	1·3 (1·2, 1·4, 1·4)	+
Magrahat (Dt. Murshidabad)	3·1 (3·2, 3·2, 3·0)	4·3 (3·4, 4·8, 4·3)	+
Maldah (Dt. Maldah)	0·3 (0·5, 0·2, 0·3)	0·8 (1·1, 0·8, 0·6)	—
Nayagram (Dt. Midnapur)	4·0 (3·1, 3·4, 5·0)	4·3 (5·2, 3·4, 4·4)	+
Noada (Dt. Murshidabad)	3·2 (2·5, 4·0, 3·1)	4·3 (3·9, 4·4, 5·7)	++
Rajnagar (Dt. Midnapur)	3·1 (1·6, 4·8, 3·0)	6·1 (8·3, 5·0, 5·2)	++
Sagardighi (Dt. Murshidabad)	0·7 (0·4, 1·2, 0·6)	1·2 (1·2, 1·2, 1·1)	—
Sirshia (Dt. Birbhum)	4·3 (4·2, 4·4, 4·4)	1·3 (1·1, 1·4, 1·3)	+
Sonarpur (Dt. 24-Parganas)	2·5 (2·5, 2·4, 2·5)	3·3 (2·8, 3·8, 3·3)	+
Suri (Dt. Birbhum)	5·0 (6·5, 3·1, 5·3)	6·4 (7·2, 6·3, 5·7)	++

++present in large numbers ; + present ; ± doubtful ; —absent.

Discussion

The results show that the tank silts give rise to algal growths in mineral solution and when these are transferred to fresh mineral solution free from combined nitrogen, growth and nitrogen fixation take place. The observation suggests that when a soil is treated with tank silt, algal population of the soil would probably increase its nitrogen content.

As no attempt has been made, during the present investigations, to isolate the algae in pure cultures, it is not known if the fixation of nitrogen is due to the algae themselves or to the organisms associated with them. But that nitrogen fixing organisms are invariably associated with the algal growths is evident from the fixation of nitrogen in Ashby's mannite solution kept in the dark. Jones (*loc. cit.*) had detected *Azotobacter chroococcum*, *Clostridium pastorianum* and *Rhizobium* in algal sheaths. Of these, only *Azotobacter* has been studied in some detail during present investigations. It is seen that appreciable fixation of nitrogen is very often associated with presence of *Azotobacter* in the algae in large numbers.

The difference in the nature of the nitrogen fixing flora of different tank silts may be responsible for the differences in the nitrogen fixations by mixed algal growths and also by the associated organisms.

In several cases, algae in association with the organisms fixed more nitrogen than the organisms alone, while there are also cases, when the organisms alone fix more nitrogen than the algal growths. The latter are more numerous than the former. In cases, where mixed algal growths show higher nitrogen fixation than the associated organisms alone, nitrogen fixation by algae, independent of the associated organisms may be visualised but that can be ascertained only after isolation of individual alga and determination of its nitrogen fixing capacity. The fixation of nitrogen by the mixed impure cultures are, however, very much lower than what had been observed, during the same period of two months, in the case of that by pure cultures of *Anabena variabilis* [Allison and Morris *loc. cit.*] and *Nostoc muscorum* [Allison, Hoover and Morris *loc. cit.*].

Summary and Conclusions

Samples of tank silts from 21 villages from different parts of West Bengal were inoculated into sterile nitrogen-free Benecke's solution kept in flasks exposed to light near a window and small portion of algal growth obtained after a period of one month was transferred to (1) fresh nitrogen-free Benecke's solution kept in flasks in light to allow growth of algae and to (2) Ashby's mannite solution kept in an incubator at room temperature to allow only the growth of the organisms associated with the algae. After a period of two months, the nitrogen content of the materials in the flasks was determined.

It was observed that nitrogen fixation by the impure mixed algae varied from 0·3 to 5·0 mg. and that by the organisms associated with the algae varied from 0·8 to 6·7 mg. during a period of two months.

Presence of *Azotobactor* in large numbers was always detected with the algal growths whenever appreciable fixation of nitrogen by the latter was observed.

Fixations of nitrogen in soil when tank silts were incorporated with it might be due to algal growths harbouring nitrogen fixing organisms.

REFERENCES

Allison, F. E. and Morris, H. J. (1930). Nitrogen fixation by blue green algae, Sci. *71*, 221-223, Nitrogen fixation by soil algae *Proc. 2nd. Int. Congr. Soil Sci.*, 24-28

—— and Hoover, S. R. (1935). Conditions which favour nitrogen fixation by blue green algae Trans. 3rd *Int. Congr. Soil Sci.*, I, 145-147

—— and Morris, H. J. (1937). Physiological studies with the nitrogen fixing alga Nostoc muscorum *Bot. Gaz.*, **98**, 433-463

De, P. K. (1939). The role of blue green algae in nitrogen fixation in rice soils *Proc. Roy. Soc.*, B *127* 121

Fogg, G. E. (1942). Studies on nitrogen fixation by blue green algae I. Nitrogen fixation by Anabena cylindrica Lemm. *J. Exp. Biol.*, **19**, 78-87

Jones, J. (1930). An investigation into the bacterial associations of some cyanophyceae with special reference to their nitrogen supply *Ann. Bot.*, **44**, 721-740

Moore, B., Wheetley, E. and Webster, T. A (1921). Studies of the photosynthesis of marine algae *Proc Roy.*, Soc. B **92**, 51-60

Prasad, M. and Patwabardhan, N. K. (1941). Studies on physico-chemical changes in black cotton soil during nitrification *Indian J. Agric. Sci.* 2 9-78-992

Sen, Abhiswar and Asija, G. L. (1953). A study of the action of tank silt on soil *Indian J. Agric. Sci.*, **23**, 223-231

—— (1954). Action of tank silt on soil II *Indian J. Agric Sci.*, **24**, 51-63

Singh, R. N. (1942). The fixation of elementary nitrogen by some of the commonest blue green algae from the paddy field soils of the United Provinces and Bihar *Indian J. Agric. Sci.*, **12**, 743-756

STUDIES ON A MOSAIC DISEASE OF *VIGNA CYLINDRICA* SKEELS

By S. P. Capoor, and P. M. Varma, Division of Mycology and Plant Pathology
Indian Agricultural Research Institute, New Delhi

(Received for Publication on March, 24 1955)

(With Plate I)

In 1947 a mosaic disease of *Vigna catjang* Walp. (*Vigna cylindrica* Skeels), locally known as *chavali*, was recorded in Bombay State [Capoor *et al.*, 1947]. The disease, which was named as catjang mosaic, was widespread in Poona and the surrounding areas where it was first discovered in 1942. It was, however, observed to spread rapidly during *kharif* season in the luxuriously growing crop of *chavali*, and to cause extensive damage. In the case of early infection and high incidence of mosaic, *chavali* plants became chlorotic and showed severe retardation of growth with the result that the yields of both fodder and pods were reduced considerably. This article deals at some length with the description of the disease, its transmission and host range, and the properties of the causal virus.

Earlier, a mosaic disease of cowpea was reported in India from the Punjab [Vasudeva, 1942], and similar diseases of the cowpea have been studied in China [Yu, 1946], in Trinidad [Dale, 1943 ; 1949], and in the United States of America [Elliot, 1921 ; Smith, 1924 ; Gardner, 1926, McLean, 1941]. A seed-borne mosaic disease of asparagus bean (*Vigna sesquipedalis* Fruwirth) was also described from America by Snyder [1942]. Recently Warid and Plakidas [1950] reported occurrence of viruses naturally infectious to cowpea in Oklahoma and Louisiana.

Material and Methods

The catjang mosaic virus used in the present study was derived from an infected seedling of *Vigna catjang* grown from a stock of seed collected from naturally infected plants. The virus was maintained by successive transfers by mechanical inoculation to healthy seedlings.

Mechanical inoculations were done with freshly extracted juice of leaves of diseased plants by the leaf-rubbing method, and using carborundum of 600-mesh fineness as an abrasive. In tests to determine the host range of the virus, plants were grown from seed and were similarly inoculated.

The insects used in the transmission tests were first colonised on diseased *chavali* plants in the insectory and then removed with a sable hair brush to a clean Petri dish before transferring them to healthy seedlings of the test plants. These were allowed to feed on them for at least 24 hours and then destroyed by spraying with nicotine sulphate.

Symptomatology

The symptoms of the disease are a typical mosaic mottling, and appear almost similar in asparagus bean, *chavali*, and in all the susceptible varieties of cowpea.

The first symptom of the disease in *chavali* appeared from 7 to 19 days after inoculation of healthy seedlings in the form of faint but distinct vein-clearing of the newly formed trifoliate leaf. This was followed by the formation of broad chlorotic spots locally. These spots did not become necrotic lesions nor was the chlorosis associated with the veins as has been observed in the case of the Trinidad cowpea mosaic [Dale, 1949]. In leaves developing subsequently the virus initiated a typical mosaic pattern of irregular light and dark green areas and blistering and malformation of leaf-lamina often accompanied by chlorotic patches (Plate I, Fig. 1). It was observed that symptoms of mosaic in *chavali* may vary extensively depending on weather conditions. The infected plants bore a distinctly chlorotic appearance with leaves reduced in size and malformed, and yielded few pods which were pale in colour, small in size, and often distinctly mottled.

Transmission of the virus

Mechanical inoculation : The catjang mosaic virus was easily transferred from diseased to healthy seedlings in 7 to 19 days by means of juice inoculation.

Seed transmission. As has been reported earlier, the catjang mosaic virus was found to be carried in about 4 per cent of the commercial seeds of *chavali* [Capoor *et al.*, 1947]. Gardner [1927] was the first to report seed-transmission of a cowpea mosaic. Later, McLean [1941], Snyder [1942], Yu [1946], and Dale [1949] also reported seed transmission of the respective mosaic viruses affecting cowpea.

Seeds were, therefore, collected exclusively from diseased plants of *chavali* and cowpea, and grown in the glasshouse for the estimation of the extent of seed transmission of the virus in diseased plants only. Out of 890 seeds of *chavali* and 72 of cowpea sown, only 791 of *chavali* and 15 of cowpea germinated. Of these 137 seedlings of *chavali* and 15 of cowpea were diseased showing that the virus was carried in 17·32 and 22·7 per cent seeds of *chavali* and cowpea, respectively. The disease appeared as faint mosaic mottle and slight wrinkling of the coteledonary leaves, but the typical symptoms of mosaic were distinctly shown by the first trifoliate leaf (Plate I, Fig. 2).

Insect transmission : Among the insects that usually colonise *chavali*, the bean aphid, *Aphis medicaginis* Koch., was found to be in abundance. Occasionally, small colonies of *Aphis gossypii* Glover and *Myzus persicae* (Sulz.) were also collected. A species of thrips, *Taeniothrips* spp., was also found feeding in large numbers on flowers and buds of *chavali*. These insects as well as *Aphis nerii* B. de F. collected from *Calotropis gigantea* Ait., were used in the transmission tests.

FIG. 1. Leaf of *Chavali* showing mosaic of broad, chlorotic and dark-green patches, and malformation of lamina.

FIG. 2. Seedling of *Chavali* grown from seed of a diseased plant. Note the mosaic symptoms even in the cotyledonary leaves, though the first trifoliate leaf shows pronounced symptoms of mosaic and blistering.

FIG. 3. Leaf of cowpea showing typical mosaic symptoms.

FIG. 4. Leaflets of *Phaseolus lunatus* showing typical mosaic symptoms induced by the virus.

FIG. 5. Leaflets of *Canavalia ensiformis* showing profuse blistering and mosaic.

FIG. 6. Leaves of *Crotalaria juncea* showing mild mosaic and discoloration of entire leaf. Healthy leaf on right.

The insects were first colonised on diseased plants and then transferred to healthy seedlings of *chavali*, and allowed to feed on them for 24 hours. *Aphis gossypii*, *A. nerii*, and *Myzus persicae*, which did not colonise on *chavali* in the glasshouse were usually starved for 4 hours before feeding them on diseased plants.

Except *A. nerii*, the other three species of aphis transmitted the virus, and *A. medicaginis* was the most efficient vector (Table I). As this is the only aphid that mostly colonises *Vigna cylindrica*, it is assumed that *A. medicaginis* is largely responsible for the spread of the virus in plants. Thrips did not transmit the virus at all.

TABLE I

Insect-transmission of catjang mosaic virus

Insect used	Test plants inoculated	Plants infected
Aphis medicaginis	59	25
Aphis gossypii	32	4
Aphis nerii	12	0
Myzus persicae	32	12
Taeniothrips spp.	16	0

Host range

The catjang mosaic virus was readily transmitted by means of mechanical inoculation to *Vigna sinensis* Savi (cowpea), *Vigna sesquipedalis* Fruwirth (asparagus bean), *Phaseolus lunatus* L. var. *macrocarpus* Benth. (double bean), *Canavalia ensiformis* DC. (Jack bean), *Crotalaria juncea* L. (sunn hemp), and *Glycine max* Merr. (soybean).

In cowpea (Plate I, Fig. 3) and asparagus bean, the virus initiated leaf distortion and mosaic mottling more or less resembling that in *chavali*. These plants were comparatively tolerant to infection with the catjang mosaic virus and the disease symptoms were milder than those observed in *chavali* itself.

Inoculation of *Phaseolus lunatus* var. *macrocarpus* (Plate I, Fig. 4) and *Canavalia ensiformis* (Plate I, Fig. 5) produced in them a disease characterised by the production of a mosaic pattern of light and dark-green patches with occasional blistering of lamina, and accompanied by reduction and deformity of leaves. In sunn hemp (Plate I, Fig. 6) and soybean the virus produced faint mosaic and discoloration of leaves which were reduced in size. Inoculation of *guar* (*Cyamopsis tetragonoloba* (L.) Taub.) gave rise locally to numerous necrotic lesions.

No infection was obtained on any of the following plant species : *Phaseolus vulgaris* L., *P. aconitifolius* Jacq., *P. trilobus* L., *P. mungo* L., *P. aureus* Roxb., *Dolichos lablab* L., *D. biflorus* L., *Lathyrus sativus* L., *Cajanus cajan* Millsp., *Stizolobium deeringianum* Bort., *Vicia faba* L., *Crotalaria retusa* L., *Sesbania speciosa*

Taub. ex Engl., *Medicago sativa* L., *Nicotiana tabacum* L., *N. rustica* L., *N. glutinosa* L., *Petunia hybrida* Vilm., *Physalis peruviana* L., *Datura inoxia* Mill., *Lycopersicon esculentum* Mill., *Capsicum frutescens* L., *Solanum nigrum* L., *S. melongena* L., *Lagenaria siceraria* Standl., *Cucumis sativus.* L., *Cucurbita pepo* L., *Tropaeolum majus* L., *Spinacia oleracea* L., and *Zinnia elegans* Jacq.

Following a wide host range study of the catjang mosaic virus it became evident that it was infectious only to a limited number of plant species in the family *Leguminosae*. *Vigna cylindrica* (*V. catjang*) could not be infected by the asparagus bean mosaic virus [Snyder, 1942], while it had not been tested with the cowpea mosaic of China [Yu, 1946] and that of Trinidad [Dale, 1949]. *Phaseolus vulgaris* could be infected only by the asparagus bean mosaic virus. Catjang mosaic produced systematic mosaic mottling in *Canavalia ensiformis* while the Trinidad cowpea virus produced in it only chocolate-brown necrotic local lesions, and it could not be infected by the cowpea mosaic of China. The catjang mosaic and the cowpea mosaic of China were not infectious to *Dolichos lablab* and the Trinidad virus produced only local lesions in it. However, all the four cowpea mosaic viruses and the catjang mosaic virus resemble each other in their inability to infect any plant species tested outside Leguminosae.

Differences in susceptibility of cowpea varieties to catjang mosaic virus

A number of cowpea varieties were tested for infection with the catjang mosaic virus by sap inoculation and have been classified into three groups on the basis of their reactions. The data are set out in Table II.

TABLE II

Susceptibility of cowpea varieties to the catjang mosaic virus

Group	Variety	Plants inoculated	Plants infected	Percentage infection	Symptoms
I	Clay No. 1	6	6	100·0	Severe mosaic
	Conch	6	6	100·0	do.
	Groit	6	6	100·0	do.
	Honolulu	12	12	100·0	do.
	Red Ripper	12	12	100·0	do.
	V 443 (Ceylon)	12	12	100·0	do.
	V 248 (Ceylon)	36	30	83·3	do.
	Whippoorwill	12	9	75·0	do.
	Victor	36	24	66·6	Chlorotic spotting and mosaic

TABLE II—*contd.*

Susceptibilty of cowpea varieties to the catjang mosaic virus

Group	Variety	Plants inoculated	Plants infected	Percentage infection	Symptoms
I	New Era	14	8	57·1	Severe mosaic and chlorosis between veins
	Black	6	3	50·0	Severe mosaic
	Early Red	31	13	41·9	Mosaic mottling
	Cream Crowder	25	8	32·0	Severe mosaic
II	Rice Suwannee	26	6	23·0	Mild mosaic
	Iron	12	2	16·6	do.
	Alacrowder	14	1	7·1	Extremely faint mottling
	Lady	24	1	4·2	Very mild mosaic
III	Early Sugarcrowder	16	0	0·0	No visible symptoms of mosaic
	Suwannee	15	0	0·0	do.
	Taylor	16	0	0·0	do.

Plants of the varieties in group I showed severe mosaic accompanied by leaf malformation and reduction, and also dwarfing of vines. These varieties are, therefore, considered as highly susceptible.

In the second group the plants which were infected developed either mild mosaic mottling or a mild chlorotic etching. There was no malformation or reduction of leaves, or dwarfing of vines. Also the percentage of plants which were infected in this group was low, and the diseased plants did not show any appreciable reduction in growth. The varieties in this group are classed as slightly susceptible.

None of the varieties in the third group showed any visible symptoms of the disease, except for an occasional appearance of fleeting chlorotic etching on some plants of the variety Suwannee. These varieties are classed as highly tolerant and may be considered comparatively resistant under field conditions.

Physical properties of the virus

The thermal inactivation, longevity *in vitro*, and tolerance to dilution of the catjang mosaic virus were determined in the usual manner with freshly extracted juice from leaves of diseased *chavali*. After treatment, the juice was inoculated to

young *chavali* seedlings, in the first trifoliate leaf-stage, using carborundum as an abrasive. The virus was inactivated on heating for 10 minutes at 90°C, and after storage for 19 days at laboratory temperature (24°C). Transmission occurred at dilutions up to 1 : 50,000; but not at 1 : 100,000 (Table III).

TABLE III

Thermal inactivation, longevity in vitro, *and tolerance to dilution of the catjang mosaic virus*

Thermal inactivation (10 minutes)

Temperature (°C.)	Plants inoculated	Plants infected	Temperature (°C.)	Plants inoculated	Plants infected
42	12	11	82	24	15
52	12	12	85	24	14
62	12	10	90	24	0
72	12	8	92	24	0

Longevity in vitro

Age (days)	Plants inoculated	Plants infected	Age (days)	Plants inoculated	Plants infected
0	14	14	6	14	6
1	14	12	9	14	4
3	14	9	15	14	2
4	14	7	19	14	0
5	14	7	26	8	0

Tolerance to dilution

Dilution	Plants inoculated	Plants infected	Dilution	Plants inoculated	Plants infected
Undiluted	40	40	1 : 5,000	40	22
1 : 10	40	40	1 : 10,000	40	15
1 : 100	40	40	1 : 50,000	40	3
1 : 1,000	40	40	1 : 100,000	40	0

Effect of desiccation : Leaves of diseased *chavali* plants were desiccated over 'desigel' S at the laboratory temperature (24°C.) for 6 days. Dried leaves were then crushed, soaked in small quantity of water, and then thoroughly ground in mortar for extracting the juice which was then tested by inoculating *chavali* seedlings. None of the twelve inoculated plants were infected, showing that the virus was completely inactivated by desiccation at room temperature.

Identity of the virus

Catjang mosaic virus resembles in its symptom expression the four cowpea mosaic viruses described by McLean [1941], Snyder [1942], Yu [1946], and Dale [1949], respectively ; but in its host range it shows closer affinity to the cowpea mosaic of McLean [1941], asparagus bean mosaic [Snyder, 1942], and the cowpea mosaic of China [Yu, 1946]. Though the physical properties of the catjang mosaic virus show a close resemblance to those of the Trinidad cowpea mosaic virus [Dale, 1949], the former is distinct from the latter because in nature it is transmitted by aphids and not by the leaf-beetles. Another characteristic behaviour in which the catjang mosaic virus differs from that of the Trinidad cowpea mosaic is its inability to infect *Dolichos lablab*, and its readiness to initiate systemic infection in *Canavalia ensiformis*. Also, catjang mosaic virus does not appear to be either a strain of cucumber mosaic virus, or even related to it, since it was unable to infect *Cucumis sativus*, *Lagenaria siseraria*, and *Cucurbita pepo*. No comparison can be drawn with the cowpea mosaic virus reported from North India [Vasudeva, 1942], and also the three *Vigna* viruses reported to be naturally occurring on cowpea in America [Warid and Plakidas, 1950] as these have not been fully studied. Recently Warid and Plakidas [1952] reported the thermal inactivation of the *Vigna* viruses. On the basis of their thermal inactivation alone it may be concluded that the catjang mosaic virus is not related to any of the *Vigna* viruses of Warid and Plakidas. Oliveira [1947] also reported occurrence of three viruses causing mosaic disease in cowpea, but details on the identity of these viruses are also not available.

Collectively these observations serve to indicate that the mosaic disease of *chavali* is caused by a virus which is distinct from that described from Trinidad [Dale, 1949], but may be closely related to the viruses causing mosaic diseases of cowpea in the U. S. A. [McLean, 1941 ; and Snyder, 1942] and in China [Yu, 1946], although differing from them in its physical properties.

The published descriptions of the mosaic diseases of cowpea also indicate conclusively that only two distinct viruses are involved in the aetiology of these diseases. One of these is an aphid-transmitted virus (and perhaps its strains), which is responsible for the cowpea mosaic diseases described by McLean [1941], Snyder [1942], and Yu [1946], and the catjang mosaic virus considered herein. The other virus reported by Smith [1924] and Dale [1949], is transmitted by leaf-beetles in nature.

The virus studied herein has been named as 'catjang mosaic virus' previously [Capoor *et al.*, 1947]. It is proposed to designate it as *Marmor vignae* var. *catjang* according to Holmes [1948], who has called the cowpea mosaic virus of McLean [1941] as *Marmor vignae.*

Summary

A mosaic disease of *Vigna catjang* Walp. (*Vigna cylindrica* Skeels), locally known as *chavali*, is described. The disease is characterised by typical mosaic pattern of irregular light and dark-green areas and blistering and malformation of leaf lamina often accompanied by chlorotic patches.

The causal virus was transmitted from diseased to healthy plants both by inoculation of expressed juice and by *Aphis medicaginis* Koch., *A. gossypii* Glover, and *Myzus persicae* (Sulz.), but not by *Aphis nerii* B. de F. or thrips. *Aphis medicaginis* was found to be the most efficient vector.

The virus is seed-borne. Seeds of *chavali* and cowpea were found to carry the virus in 17·32 and 22·7 per cent, respectively, of the seed collected exclusively from diseased plants.

The host range and varietal differences in susceptibility of 20 cowpea varieties were tested. These varieties are classified into three groups according to their susceptibility or tolerance to mosaic infection.

The virus was inactivated by heating for 10 minutes at 90°C, but not at 85°C, at a dilution of 1 in 100,000 but not at 1 in 50,000; and after storage for 19 days. It was, however, completely inactivated by desiccation.

The virus is not related to the cowpea mosaic of Trinidad or to cucumber mosaic virus but is related to the viruses causing mosaic in cowpea recorded by McLean and Snyder from the U.S.A., and by Yu from China, although differing from them in its physical properties. On the basis of these differences the virus which is, commonly called as 'catjang mosaic virus', has been designated as *Marmor vignae* var. *catjang* according to Holmes' classification.

Acknowledgments

Grateful thanks are due to Dr R. S. Vasudeva, Head of the Division of Mycology and Plant Pathology for very kindly helping in the preparation of the manuscript and to Dr B. N. Uppal, *now* Agricultural Commissioner with the Government of India, for encouragement during the course of these studies. Thanks are also due to the Indian Council of Agricultural Research for financing a scheme under which the present investigation was carried out.

References

Capoor, S. P., Varma, P. M. and Uppal, B. N. (1947). A mosaic disease of *Vigna catjang* Walp. *Curr. Sci.*, *16*, 151

Dale, W. T. (1943). Preliminary studies of the plant viruses of Trinidad. *Trop. Agric.* 20 : 228

—— (1949). Observations on a virus disease of cowpea in Trinidad. *Ann. appl. Biol.*, 36 : 327-333

Elliot, J. A. (1921). A mosaic of sweet and red clovers. *Phytopath.*, 11, 146-148

Gardner, M. W. (1926). Indiana plant diseases, 1925. *Proc. Indiana Acad. Sci.*, *36*, 238

———— (1927). Indiana plant diseases, 1926. *Ibid.*, *37*, 417

Holmes, F. O. (1948). *The Filterable Viruses.* Supplement No. 2. Bergey's Manual of Determinative Bacteriology. The Williams and Wilkins Company, Baltimore. 4th Edition, 1188-1189

McLean, D. M. (1941). Studies on mosaic of cowpeas, *Vigna sinensis*. *Phytopath.*, **31**, 420-430

Oliveira, M. A. (1947). *Contribuicao ao estudo dos virus causadores de mosaico nos feijoes macassar* (*Vigna* spp.) *Bol. Tech. Inst. Agron. Sul* (Pelotas), 1, 1-15. (*Biol. Abstr.*, *28* (4506) 444 ; 1954)

Smith, C. E. (1924). Transmission of cowpea mosaic by the bean leaf-beetle. *Sci.*, *60*, 268

Snyder, W. C. (1942). A seed-borne mosaic of asparagus bean, *Vigna sesquipedalis*. *Phytopath.*, **32**, 518-523

Vasudeva, R. S. (1942). A mosaic disease of cowpea. *Indian J. agric. Sci.*, **12**, 281-283

Warid, W. A. and A. G. Plakidas (1950). New viruses naturally infectious to cowpea. *Phytopath.*, *40*, 30

———(1952). Thermophilic viruses naturally infectious to cowpea. *Plant Dis. Rep.*, **36** (*10*), 380-381

Yu, T. F. (1946). A mosaic disease of cowpea (*Vigna sinensis* Endl.) *Ann. appl. Biol.*, **33**, 450-454

STATISTICAL STUDIES OF THE CROP YIELD DATA OF THE PUSA PERMANENT MANURIAL EXPERIMENTS (New Series)

I.—STUDY OF MAIZE YIELDS

By S. Sen and A. G. Kavitkar, Indian Agricultural Research Institute, New Delhi

(Received for publication on May 3, 1955)

(With three text-figures and two appendices)

A LONG-TERM experiment is one of the most useful tools of technical advance and is indispensable for framing empirical rules for the conduct of practical agriculture. The first paper on the subject was published by Fisher [1921] in connection with his examination of the yield of dressed grain from Broadbalk. Subsequently, Mackenzie [1924] following Fisher, examined the yield of dressed grain from Hoos Field, and Kalamkar [1933] applied similar analysis to the series of yields of mangolds from the different plots of Barnfield. In India, Kalamkar and Singh [1935] analysed the wheat yield data of the permanent manurial experiments carried out at Kanpur, U.P., which were conducted for 29 years from 1885-86 to 1913-14. Bose and Menon [1937] also analysed the yields of crops of the Permanent Manurial and Rotation Experiment, Pusa, for the period 1908 to 1930. Cochran [1939] in his paper " Long Term Agricultural Experiments " remarks that owing to the considerable cost and the need for earmarking part of resources of an experimental station for many years, the number of these experiments which are undertaken is small, though the subject calls essentially for first-hand knowledge of the actual problem. Further, the wide diversity of types of such experiments makes it difficult to find rules of procedure, and each experiment has to be considered on merit.

It is, therefore, of considerable importance to attempt the statistical analysis of crop yield data of long-term experiments. An opportunity for such investigation was provided by the yield data pertaining to a long-term experiment which has been in progress at Pusa, North Bihar since 1932.

This long-term experiment was started with a view to determining under subtropical climatic conditions, the specific effects on soil fertility of the more important organic manures and inorganic fertilizers, applied alone and in various combinations, to crops grown in a rotation, as the old Permanent Manurial Experiments, first laid down in 1908, were considered later as unsatisfactory from the point of view of (i) want of randomization, and (ii) inadequate replications. The first defect led to a biased estimate of error and the second to a loss of precision. The new series was

laid out in *kharif* 1932 in randomized blocks with 10 replications. The following 10 treatments were included in the experiment:

A. No manure (control).

B. Farmyard manure at 8000 lb. per acre=40 lb. of N per acre (total amount applied in the last week of April or first week of May).

C. Rape cake at 40 lb. N per acre (half applied just before maize sowing and half applied at the last interculture of maize).

D. Sulphate of ammonia at 40 lb. N per acre.

E. Sulphate of potash at 50 lb. K_2O per acre.

F. Superphosphate at 80 lb. P_2O_5 per acre.

G. Sulphate of potash at 50 lb. K_2O+ superphosphate at 80 lb. P_2O_5 per acre.

H. Sulphate of ammonia at 40 lb. N + sulphate of potash at 50 lb., K_2O + superphosphate at 80 lb. P_2O_5 per acre.

I. Sulphate of ammonia at 40 lb. N + superphosphate at 80 lb. P_2O_5 per acre.

J. Sulphate of amonia at 40 lb. N + sulphate of potash at 50 lb. K_2O per acre.

The inorganic fertilizers alone and in various combinations were applied half before *kharif* sowing and half before *rabi* sowing.

Rotation : The following fouryear eight-course rotation was followed :

Year	*Kharif*	*Rabi*
First year	Maize	Oats
Second year	Maize	Peas
Third year	Maize	Wheat
Fourth year	Maize	Gram

Plot size : The plot size was, for maize, 37·5 ft. ×18 ft. or 1/64·53 acre and for other crops, 40 ft. ×20 ft. or 1/54·45 acre after excluding the border crop.

The soil of Pusa is Gangetic alluvium, mostly light loam and highly calcareous in nature. The total nitrogen, organic carbon and available P_2O_5 contents vary from 0·032 to 0·045 per cent, 0·26 to 0·37 per cent, and 0·0039 to 0·0068 per cent respectively. The calcium carbonate content is very high, being 35 to 40 per cent. The *p*H of the soil is 8·0 to 8·1.

The crops in North Bihar are grown under rainfed conditions. No irrigations were given to any of the crops in this experiment. The average monthly and annual rainfall during 20 years from 1932-33 to 1951-52 were as follows :

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av. per annum
0·56	0·82	0·29	0·46	1·97	6·80	10·95	11·39	8·50	2·35	0·15	0·05	44·29 inches.

The yield data relating to the various treatments in different replications recorded from 1932-33 to 1951-52 for maize have been taken up for statistical examination in this paper with a view to studying (i) the changes in mean yields from year to year and cumulative effect of treatments, and (ii) the causes of variation in the yields.

Analysis of maize yields for 20 years

The changes in mean yields from year to year and cumulative effect of treatments

(*a*) *Testing of treatments in individual years :* The yield data were analysed by the method of analysis of variance [Fisher, 1941] separately for each year, and different treatments were compared to see the changes in mean yields from year to year. The treatment sum of squares from the individual analysis were further divided into nine different components, orthogonal to each other. The sub-division was made with a view to studying the following :

(i) Significance of main effects of nitrogen, phosphorus, and potash.

(ii) Significance of interactions : NP, NK, PK, and NPK.

(iii) Comparison of organic manures, viz. farmyard manure and rape cake.

(iv) Comparison of organic manures and inorganic fertilizers.

The first three sets of comparisons or effects have physical interpretations. The last one constitutes the remaining component orthogonal to all the effects in the first three sets.

(*b*) *Study of cumulative effect of treatments :* For each plot, the yields for 20 years were added up and the plot totals analysed by the method of analysis of variance to study the cumulative effect of different treatments over the period under study.

The treatment differences were tested against the interaction of treatments and blocks, which is the appropriate error in this case.

The treatment sum of squares were then partitioned into the various components following the same method as described under (*a*) above.

The causes of variation in the yields

The changes in yield may be ascribed to three causes, viz. (i) steady deterioration, (ii) slow changes other than steady deterioration, and (iii) annual variation. Fisher [1921], in connection with his examination of the yield of dressed grain from Broadbalk, distinguished these three types of variations in the wheat yields. The steady deterioration was represented by the linear term of the regression of yield on years. The quadratic to quintic terms represented slow changes and the remainder of the variation was considered as annual variation. An attempt has, therefore, been made to classify these three kinds of variations in maize yields, since such a study would be helpful in judging the performance of the different treatments in the light of the above causes. A treatment could be considered good only if it is less susceptible to annual variations, does not undergo slow changes, arrests the deterioration in soil fertility, and brings about increase in yields.

Results of statistical analysis

The changes in mean yields from year to year and cumulative effect of treatments

In Table I, the average yield of maize grain for each year and cumulative effects in maunds per acre are given against each treatment with appropriate standard

TABLE I

Treatment effects in individual years on maize (Yield in maunds per acre)

Years	A	B	C	D	E	F	G	H	I	J	S. Em	C.D. at 5 per cent	C.D. at 1 per cent	Remarks
1932-33	13·95	16·83	20·00	15·78	14·28	14·59	13·16	17·18	17·18	16·60	±0·96	2·72	8·61	'F' significant at 1 per cent.
1933-34	3·24	5·39	11·02	4·47	3·59	3·54	2·59	5·02	6·16	4·57	±0·56	1·58	2·09	do.
1934-35	7·64	11·89	17·56	12·06	7·97	9·78	7·65	13·55	13·63	11·60	±0·94	2·64	3·50	do.
1935-36	4'70	8·30	10·84	5·75	4·43	4·92	4·23	8·49	7·80	6·81	±0·67	1·87	2·49	do.
1936-37	4·00	10·32	14·89	8·75	5·66	5·95	4·52	9·89	12·12	7·80	±0·85	2·40	3·18	do.
1937-38	4·78	11·63	13·84	8·70	4·81	5·23	4·37	10·88	11·58	9·01	±0·56	1·59	2·11	do.
1938-39	0·57	2·39	3·76	1·37	0·84	1·12	1·07	1·89	1·91	1·25	±0·27	0·78	1·04	do.
1939-40	2·50	7·37	9·88	5·91	3·17	4·08	2·88	6·42	6·59	5·21	±0·58	1·63	2·16	do.
1940-41	6·16	15·09	17·77	9·93	6·89	9·51	6·97	12·82	12·55	8·21	±1·35	3·80	5·04	do.
1941-42	0·98	5·17	7·03	2·71	1·16	1·91	1·12	4·00	3·70	2·49	±0·57	1·62	2·13	do.
1942-43	3·07	6·63	7·23	6·60	3·19	3·60	2·15	6·10	5·78	6·71	±0·73	2·05	2·72	do.
1943-44	6·43	9·49	9·96	9·41	6·82	6·19	6·98	11·29	11·29	9·96	±0·55	1·55	2·05	do.
1944-45	2·05	6·58	7·08	5·22	2·12	2·56	1·95	5·07	4·99	5·21	±0·43	1·22	1·61	do.
1945-46	2·36	5·95	7·00	3·95	3·58	3·71	2·61	5·38	5·03	4·24	±0·46	1·29	1·72	do.
1946-47	0·89	2·02	2·27	2·01	1·00	0·82	0·60	1·85	1·71	2·58	±0·24	0·67	0·90	do.
1947-48	1·75	2·92	2·68	1·69	1·53	2·10	1·58	2·06	1·73	1·76	±0·30	0·84	—	'F' significant at 5 per cent only
1948-49	2·20	5·13	7·41	3·06	2·31	3·73	2·95	3·98	4·16	2·89	±0·31	0·86	1·14	'F' significant at 1 per cent
1949-50	0·17	0·69	1·00	0·80	0·46	0·31	0·27	0·88	0·80	0·66	±0·20	—	—	'F' not significant
1950-51	2·16	5·18	5·67	5·90	2·89	2·65	2·81	4·29	4·63	4·81	±0·61	1·73	2·29	'F' significant at 1 per cent
1951-52	4·14	8·04	9·10	5·94	4·45	3·93	3·82	6·45	6·84	6·96	±0·75	2·12	2·81	do.
Cumulative effects	3·69	7·35	9·30	6·00	4·10	4·49	3·72	6·87	7·01	5·97	±0·40	1·13	1·50	'F' significant at 1 per cent.

errors. Critical differences at 5 per cent and at 1 per cent levels of significance are also recorded where 'F' test was found to be significant.

It is seen from Table I that the treatment differences for all the years, except for the year 1949-50 when the crop failed, are highly significant, and there is little variation in the order of the treatments year after year. It will, however, be observed that the treatment C (rape cake) has given significantly the best yield in most of the years. The next best treatments are B (farmyard manure), H (npk) and I (np), and they do not differ significantly among themselves. The treatments D (n), and J (nk) give higher yields than the control, and in most of the years the differences between them are significant. The other treatments A (control), E(k), F(p), and G(pk) are more or less alike and have shown poor yields.

It will also be observed that the treatment C (rape cake) has, on an average, come out to be the best, and it is significantly superior to the remaining nine treatments. The treatments B (farmyard manure), I (np) and H (npk), follow next. These treatments do not differ significantly among themselves, but the treatment B (farmyard manure) is significantly better than the treatments D (n), J (nk), F(p), E(k), G(pk) and A (control) at 5 per cent level of significance. The differences among the treatments I(np), H(npk), D(n) and J(nk) are not significant, but all of them are significantly better than the treatments F(p), E(k), G(pk) and A (control). The treatments F(p), E(k), G(pk) and A (control) did not differ significantly among themselves and yielded poorly.

The changes, year after year, in mean yields of maize under different treatments are represented in Fig. 1. It is apparent from the figure that the changes in mean yields are in the main, though not fully, expressed as simple deterioration. The mean yield rises in some years under all the 10 treatments, but there is a steady fall in the yields.

TABLE II

Main effects and interactions of nitrogen, phosphorus and potash on maize in maunds per acre

Year	Effects							
	N	P	NP	K	NK	PK	NPK	S.E.
1932-33	2·68**	0·38	0·62	−0·06	0·48	−0·64	0·24	±0·68
1933-34	1·82**	0·36	0·70	−0·40	−0·10	−0·64	0·02	±0·40
1934-35	4·24**	1·14	0·62	−0·38	0·12	−0·72	0·90	±0·66
1935-36	2·64**	0·94*	0·92	0·20	0·68	−0·20	0·02	±0·48
1936-37	4·60**	1·56*	1·16	−0·74	−0·86	−1·10	0·46	±0·40
1937-38	5·24**	1·18**	1·18**	−0·30	0·12	−0·46	−0·02	±0·40

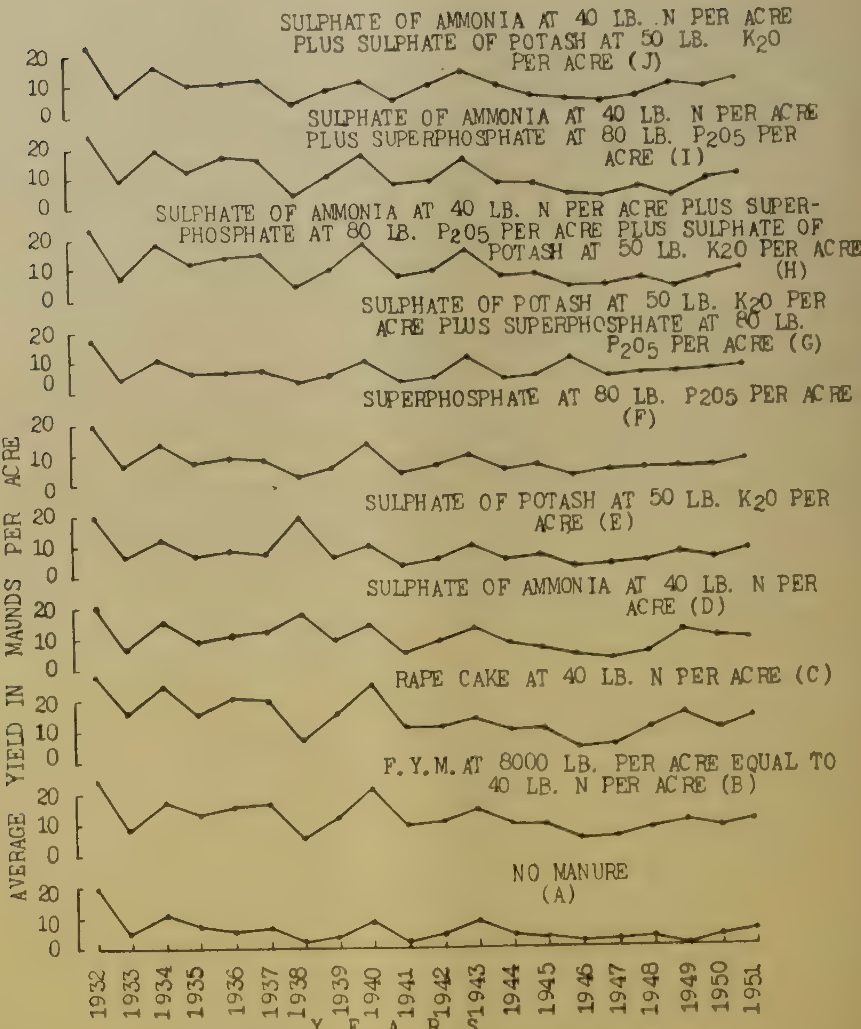


Fig. 1 Changes in mean yields of maize year after year under different treatments.

TABLE II—*contd.*

Main effects and interactians of nitrogen, phosphorus and potash on maize (in maunds per acre)

Year	Effects							
	N	P	NP	K	NK	PK	NPK	S.E.
1938-39	0·70**	0·48*	0·10	0·02	−0·08	0·06	0·10	±0·20
1939-40	2·88**	0·80	0·16	−0·36	−0·08	−0·34	0·60	±0·40
1940-41	3·50**	2·66**	0·94	−0·82	0·08	−0·32	1·32	±0·96
1941-42	1·94**	0·84*	0·40	−0·14	0·16	−0·12	0·38	+0·40
1942-43	3·30**	0·48	−0·24	−0·22	0·44	−0·34	0·44	±0·52
1943-44	3·88**	0·78*	0·82*	0·44	−0·16	−0·04	−0·24	±0·40
1944-45	2·94**	−0·02	−0·18	−0·12	0·16	−0·14	0·20	±0·30
1945-46	1·58**	0·64*	0·44	0·20	0·14	−0·56	0·60	±0·32
1946-47	1·20**	−0·38*	−0·14	0·16	0·20	−0·20	−0·02	±0·18
1947-48	0·08	0·18	0·02	0·08	0·28	−0·008	0·14	±0·22
1948-49	0·84**	0·94**	0·12	0·14	0·06	−0·10	0·08	±0·22
1949-50	0·48**	0·04	0·06	0·04	−0·08	−0·02	0·14	±0·14
1950-51	2·28**	0·34	0·54	−0·14	−0·58	0·04	0·34	±0·44
1951-52	2·46**	−0·46	0·30	−0·20	−0·10	−0·12	−0·24	±0·54
Average response	2·46**	0·58*	0·38	−0·14	0·04	−0·32	0·26	±0·28

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Table II reveals that the response to nitrogen is positive for all the years and also highly significant, except for the year 1947-48. The increase in yield due to nitrogen ranges from 0·08 maunds per acre to 5·24 maunds per acre per year. The response to phosphorus is positive in fifteen years and negative in five years, but in 9 cases out of 15, it is significantly positive and in one it is significantly negative. The interaction NP is significantly positive only for the years 1937-38 and 1943-44. The response to potash is negative in majority of the cases, but it is non-significant. The interaction NK is positive in 11 out of 20 years, but none of them is significant. The interaction PK has shown negative effects in all the years, except in the year 1950-51, but they are not significant. The interaction NPK is positive in 16 out of 20 years, but it is non-significant.

The average responses to nitrogen andphosphorus are significant and positive. Nitrogen has, however, raised the yield more than phosphorus. The other average responses are not significant, but the responses to potash and PK are negative.

The changes in responses year after year are shown in Fig. 2.

The causes of variation in the yields

(i) *Fitting of constants :* Linear and higher terms of regression upto 5th degree of yield on years were worked out separately for each treatment, and are shown in Table III.

TABLE III

Linear to higher terms of regressions upto 5th degree (in maunds per acre)

Treatments	Linear	Quadratic	Cubic	Quartic	Quintic
A (control)	−0·1488	0·03900	0·001199	0·001055	−0·00003222
B (farmyard manure)	−0·2037	0·01821	0·0006263	0·001430	0·00001794
C (rape cake)	−0·3173	0·03557	0·001086	0·001192	0·0001371
D (n)	−0·1832	0·03004	−0·0001285	0·001273	0·00008100
E (k)	−0·1559	0·03942	−0·001022	0·001041	0·00000153
F (p)	−0·1736	0·03135	−0·0009150	0·001015	−0·0001525
G (pk)	−0·1353	0·03388	−0·0009354	0·0009597	−0·0001495
H (npk)	−0·2323	0·02325	0·0001204	0·001240	0·0001553
I (np)	−0·2456	0·02877	0·0005043	0·001140	0·0001589
J (nk)	−0·1835	0·03619	−0·0004840	0·001355	0·0002990

It will be seen from Table III that the linear term is negative for all the treatments. Quadratic and quartic terms are positive. Cubic term is positive for the treatments C (rape cake), B (farmyard manure), I (np) and H (npk) and negative for the remaining ones. Similarly, quintic term is positive for the treatments J (nk), I (np), H (npk), C (rape cake), D (n) and E (k) and negative for the treatments B (farmyard manure), A (control), G (pk) and F (p).

(ii) *Significance of the regression terms :* In Table IV, the analysis of variance for testing the significance of linear to quintic terms of the regression of yield on years are shown separately for each treatment.

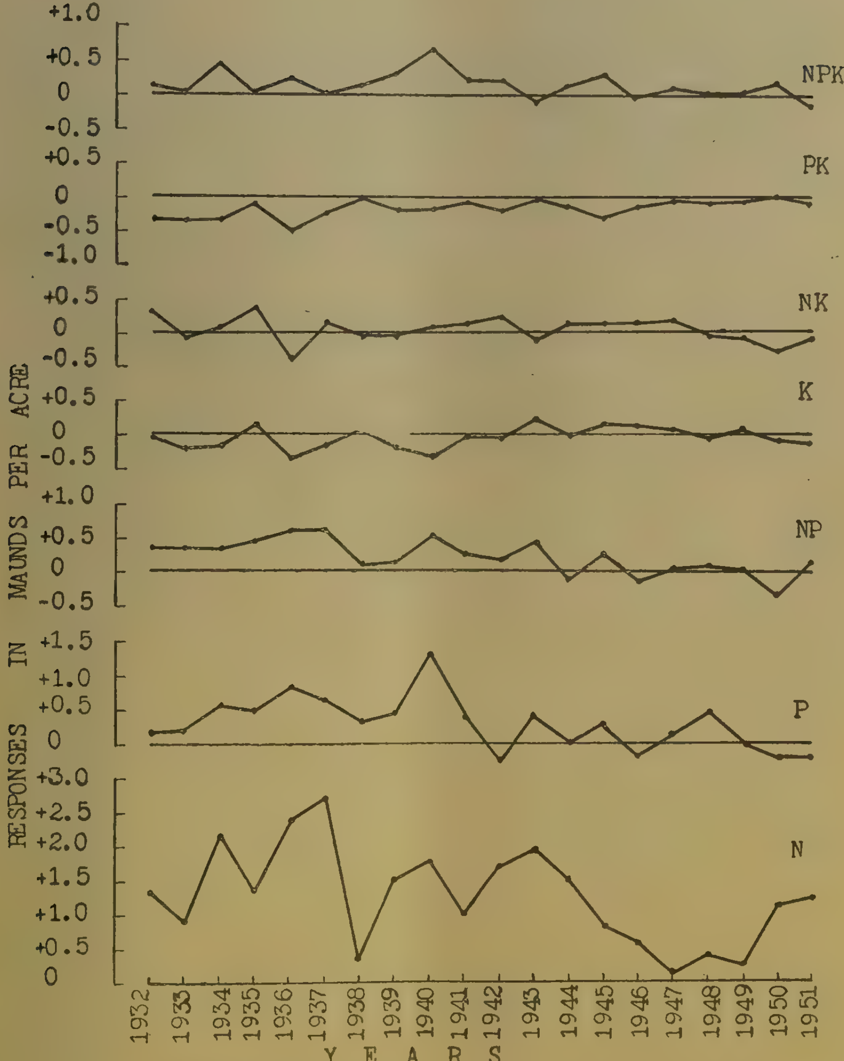


FIG. 2. Changes in responses year after year in (nitrogen), P (phosphorus) and K (potash) on maize

TABLE IV

Analysis of variance for testing significance of regression terms

	Degrees of freedom	Mean squares	Variance ratio	Mean squares	Variance ratio	Mean squares	Variance ratio	Mean squares	Variance ratio	Mean squares	Variance ratio
		Treatment	A (control)	Treatment B	(F.Y.M.)	Treatment C	(rape cake)	Treatment	D (n)	Treatment	E (k)
Linear	1	958·0078	312·55**	1795·0879	62·93**	4356·0526	233·92**	1451·2445	134·85**	1050·9163	46·07**
Error	9	3·0651		28·5243		18·6224		10·7616		22·8095	
Quadratic	1	434·2792	100·63**	94·7143	9·87*	361·3595	58·11**	257·7028	45·92**	443·8589	329·91**
Error	9	4·3154		9·5997		6·2132		5·6124		1·3454	
Cubic	1	114·6330	136·31**	31·2866	4·47	125·2816	44·27**	1·3175	0·29	83·4052	11·96**
Error	9	0·8410		6·9915		2·8299		4·6094		6·9736	
Quartic	1	414·0978	41·08**	764·3537	76·61**	528·9601	18·68**	602·5229	55·37**	403·4795	51·55**
Error	9	10·0796		9·9775		28·3188		10·8811		7·8276	
Quintic	1	0·5268	0·14	0·1633	0·02	9·4556	0·82	3·3286	0·51	0·0012	0·02
Error	9	3·8039		6·7783		11·5741		6·5442		5·0566	
		Treatment	F (p)	Treatment	G (pk)	Treatment	H (npk)	Treatment	I (np)	Treatment	J (nk)
Linear	1	1303·7713	59·86**	792·3961	73·23**	2334·5119	116·43**	2609·0496	17·77**	1455·9151	176·67**
Error	9	21·7809		10·8213		20·0511		14·6802		8·2409	
Quadratic	1	280·6576	28·01**	327·7492	30·44**	154·3266	26·23**	236·2999	26·67**	373·8263	51·90**
Error	9	10·0190		10·7673		5·8835		8·8601		7·2025	
Cubic	1	66·8254	17·15**	69·7710	56·61**	1·1559	0·10	20·2775	2·33	18·6843	3·16
Error	9	3·8955		1·2324		12·1083		8·6983		5·9207	
Quartic	1	383·9253	49·29**	342·7398	74·45**	572·3200	28·09**	483·7034	19·21**	682·9828	65·84**
Error	9	7·7890		4·6035		20·3737		25·1769		10·3734	
Quintic	1	11·8066	8·42*	11·3472	3·64	12·2353	2·98	12·8046	2·49	45·3558	16·93**
Error	9	1·4021		3·1132		4·1041		5·1407		2·6783	

** Significant at 1 per cent level

* Significant at 5 per cent level

It will be seen from Table IV that for the treatments A (control), C (rape cake), E (k), F (p) and G (pk), linear to quartic terms are highly significant and quintic term is not significant. For the treatment B (farmyard manure), linear and quartic terms are highly significant and quadratic term is significant only at the 5 per cent level, but cubic and quintic terms are not significant. In the case of the treatments D (n), H (npk) and I (np), linear, quadratic and quartic terms are highly significant and cubic and quintic terms are not significant, but for the treatment J (nk), linear, quadratic, quartic and quintic terms are highly significant and cubic is not significant.

It will further be observed that, although the higher terms of regression up to 5th degree are significant, greater proportionate variation is accounted for by the linear term. Among the higher order regressions, next to linear regression, second highest variation is accounted for by quartic term. It only indicates that there is significant rate of deterioration in all the treatments and if at all there are slow changes present in the maize yields, it could possibly be represented by 4th degree curve.

(iii) *Goodness of fit :* The analyses of variance under each treatment are recorded separately to test whether the process of fitting has been carried far enough to represent changes of the mean, and also to have distinction between the slow changes and the annual variation.

It will be seen from Appendix I that the fitting of polynomials upto 5th degree is not quite adequate to represent the changes of the mean yields, and since the variation for slow changes and that of remainder of annual variation is of the same order, it is not possible to identify the two variations. The test appears to suggest, therefore, that there are no slow changes present in the yield. Fitting of constants was carried further up to 9th degree term, but no significant reduction of residual variance could be had. Hence the process was discontinued.

(iv) *Correlation of residuals :* Correlations between harvests 1, 2, 3 up to 6 years apart and residuals were then worked out to identify slow changes and annual variation. Appendix II shows the values of correlations between harvests, the mean correlations, standard errors, mean expected correlations and the values of the correlations between residuals after fitting linear regression of yield on years taken k years apart, along with their mean correlation, mean expected correlation and standard error for each treatment separately.

It will be observed from Appendix II that the values of the mean correlations between the neighbouring values for all the treatments as compared to the mean expected correlation are significantly different and positive. This shows that the neighbouring values are associated. The mean correlations between residuals, after fitting linear regression, do not differ significantly from the expected mean correlations between residuals of k years apart and are negative. Even the individual correlations between the residuals for 1, 2, 3 up to 6 years apart do not differ significantly from the expected correlations and most of the correlations are negative.

It indicates, therefore, that the linear term is quite sufficient to represent the changes in the mean values. It means that the slow changes are not present in the

mean values. Only two kinds of variations, (i) steady deterioration and (ii) annual variation are distinguishable.

(v) *Comparison of linear regressions of yield on years :* In such experiments the most interesting term in the interaction of treatments with years is the comparison of the linear regression of yield on years for the different treatments, since this term indicates whether the treatment differences are becoming more or less pronounced as the experiment proceeds.

The analysis of variance for the linear regression coefficients of yield on years is shown in Table V.

TABLE V

Analysis of variance for comparing linear regression coefficients

Source	Degrees of freedom	Mean squares	Variance ratio
Blocks	9	0·02353	5·82
Treatment regressions	9	0·04853	12·01**
Error	81	0·004042	
TOTAL	99		

**Significant at 1 per cent level

The analysis indicates that the differences between the linear regressions due to treatments are highly significant.

In Table VI regression coefficients for each treatment are expressed in maunds per acre. Appropriate S. E. and C. D. at 5 and 1 per cent levels of significance are also given.

TABLE VI

Linear regression coefficients in maunds per acre treatmentwise

Treatments	Linear regression coefficients
C (rape cake)	−0·3173
I (np)	−0·2456
H (npk)	−0·2323
B (farmyard manure)	−0·2037
J (nk)	−0·1835
D (n)	−0·1832
F (p)	−0·1736
E (k)	−0·1559
A (control)	−0·1488
G (pk)	−0·1353
S. E.	±0·0158
C. D. at 5 per cent level	0·0444
C. D. at 1 per cent level	0·0588

It can be seen from Table VI that the regression coefficients for all the treatments are negative. The coefficient for the treatment C (rape cake) is the highest and is significantly different from the remaining coefficients for the nine different treatments. The coefficients for the treatment I (np), II (npk) and B (farmyard manure) do not differ significantly among themselves, but those for the treatments I (np) and H (npk) are significantly different from the coefficients of the treatments J (nk), D (n), F (p), E (k), A (control) and G (pk). The differences between the coefficients for the treatments B (farmyard manure), J (nk), D (n), and F (p) ; J (nk), D (n), F (p), E (k) and A (control) ; and F (p), E (k), A (control) and G (pk) are not significant. The coefficient for the treatment B (farmyard manure) is significantly different from those of the treatments E (k), A (control) and G (pk), and the coefficients of the treatments J (nk) and D (n) are significantly different from that of the treatment G (pk).

Table VII gives the regression coefficients for main effects and interaction of nitrogen (N), phosphorus (P) and potash (K).

TABLE VII

Linear regression coefficient for main effects and interactions

Effects	Linear regression coefficients
N	−0·05776**
P	−0·02886*
NP	−0·02676*
K	0·01105
NK	−0·00455
PK	0·01475
NPK	−0·00795
S. E.	±0·01115

** Significant at 1 per cent level

* Significant at 5 per cent level

It is clear from Table VII that the coefficient for N is highly significant and negative. Coefficients for P and NP are significant at 5 per cent and negative and those for other effects and interactions are not significant.

(vi) *Relative variance :* Having thus seen that the variation in mean yields are only of two kinds, viz., (i) steady deterioration and (ii) annual variation, the relative

variance for each of the two types of variations from Appendix I was obtained from the formula R. V.$=\frac{100\times \text{Absolute variance}}{(\text{Mean})^2}$ for all the treatments and shown diagrammatically in Fig. 3 with a view to comparing the relative variation for each treatment separately. The annual variation accounts for a greater proportion of the total variation than the deterioration. It will, however, be observed that the annual variation is small on all the plots receiving organic manures, but the plots receiving npk ' complete artificials ', or np, nk and n are not much more variable than organic manures. The relative deterioration is seen to be minimum in the case of farmyard manure treatment, but comparatively more under nitrogenous fertilizers and also under rape cake. Even greater relative deterioration is, however, observed on the plot receiving non-nitrogenous treatments.

Discussion

The preliminary survey of the maize yield data from 20 years' experimentation indicates that the various treatments tried in the experiment, brought about significant differences in yield in all the years, except 1949-50, when the crop had failed. All the treatments gave highest yields during the year of commencement of the experiment, but the yields subsequently fell off gradually, although some slight fluctuations in yield were noticed in the results for some years.

It is clear from Table I, that the treatment effects in the individual years are fairly consistent. Though the statistical analysis for the year 1949-50 did not show significant differences between the treatments, the treatments, as can be seen, follow similar trends in other years.

Rape cake has significantly raised the yield of maize in most of the years. Farmyard manure, np and npk have also given higher yields, though not as good as that of rape cake, and the differences between them are not significant. Sulphate of ammonia, though gave significantly more yield over control, is actually inferior to organic manures or np, or npk—the complete fertilizer treatment.

Main effects and interactions : The study of the main effects and interactions of nitrogen, phosphorus and potash reveals that the response to nitrogen is positive and highly significant in all the years, except 1947-48. The highest increase in yield due to nitrogen is 5·24 maunds per acre. Next to this, phosphorus and interaction NP and NPK have shown positive effects in most of the years, but the response to potash is negative.

Organic manures : The two forms of organic manures, viz. rape cake and farmyard manure differ significantly in most of the years. The rape cake treatment has given higher yields than farmyard manure throughout the period.

Cumulative effect of the treatment : The comparison of the total yields due to different treatments taken over 20 years are in agreement with the conclusions drawn

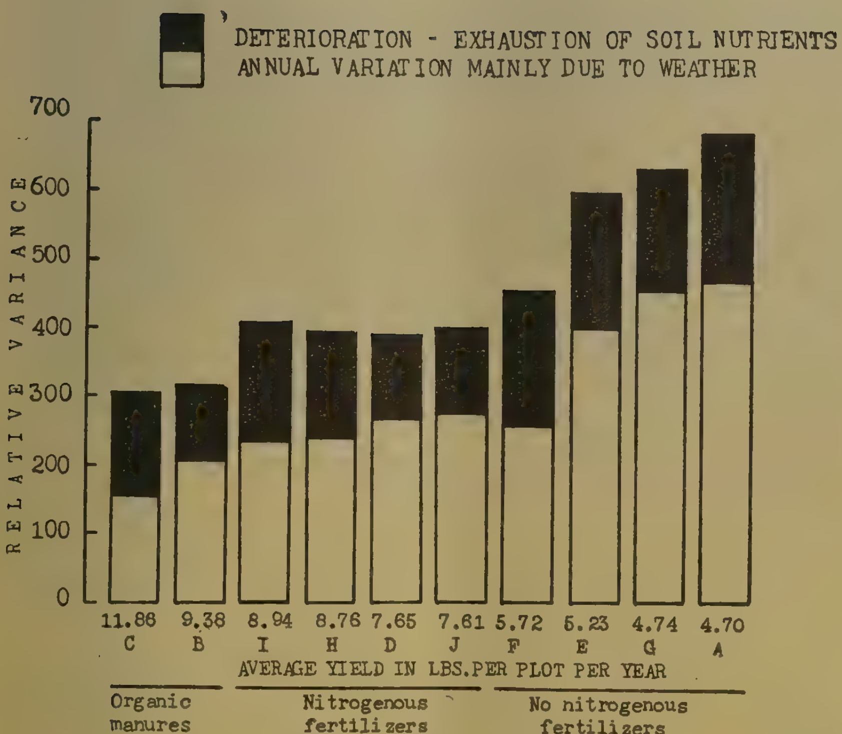


FIG. 3. Causes of variation in maize yields

above. Rape cake has, on an average, come out significantly to be the best treatment. Farmyard manure has given better yields than the control, but the response to farmyard manure is not as good as that to rape cake. The np and npk treatments have also indicated better results than the control and these do not differ significantly from the farmyard manure treatment. The chemical fertilizer treatments n, np, nk and npk containing sulphate of ammonia, have on an average significantly raised the yields over the non-nitrogenous treatments p, k and pk, and the later ones do not differ significantly from control which shows the poorest average performance. This leads one to infer that the maize crop has been benefited by the application of the nitrogenous treatments, while the non-nitrogenous treatments have practically no effect on it. This is supported by the study of main effects and interactions of nitrogen, phosphorus and potash. Among the main effects and interactions, the main response to nitrogen is highly significant and phosphorus is significant at 5 per cent level only, but the effect of potash is depressing, though it is non-significant. There is no evidence of interaction between any of the factors.

In this connection, the results obtained from the permanent manurial experiments conducted at the various research stations in this country, namely at Pusa (old series), Kanpur and Coimbatore are worth mentioning. At Pusa [Menon and Bose, 1937], the analysis of the yield data from the old series showed that in the case of maize, farmyard manure at 30 lb. nitrogen per acre and complete fertilizer treatment on the basis of 20 lb. nitrogen per acre in farmyard manure gave the best yields. The effect of rape cake at 20 lb. nitrogen per acre was not as good as that of farmyard manure (30 lb. N per acre). Superphosphate came next. Potash by itself did not show beneficial effect. Similar were the results with ammonium sulphate. At Kanpur [Kalamkar and Singh, 1935], sheep-dung gave highest yield of wheat. Cow-dung was next in order of merit. The complete fertilizer treatment also gave high yields, comparable to the organic manures. The results obtained at Coimbatore [Raju, 1952] with *ragi* (*Eleusine coracana*), *cholam* (*Andropogon sorghum*), wheat, *panivaragu* (*Panicum miliaceum*) and *cumbu* (*Pennisetum typhoides*) showed that the fertilizer treatments npk, np and cattle manure were better than n, p, k, nk and pk. These results, as well as those discussed in this paper showed that organic manures and artificial fertilizers, namely npk and np are equally beneficial to the cereal crops.

The causes of variation in the yield : The study of linear to quintic regression indicates that the linear regressions for all the treatments are highly significant and take away most of the variation. It means that all the treatments show significant deterioration. The quadratic to quintic regressions are also significant, but next to linear, quartic regressions removes the highest variation. Thus, if there are slow changes present in the yields, it could well be represented by the polynomial of 4th degree. But the test of 'goodness of fit' reveals that the changes of mean yields cannot fully be represented by even fitting the polynomials upto 9th degree. Hence, the problem arises as to the manner in which slow changes should be represented and a distinction can be made between slow changes and annual variation. For,

if the necessary number of terms of the regression polynomial are not taken for representing slow changes, there will be a confusion between the slow changes and annual variation. The comparison of correlations of residuals of various orders with their expected values (obtained on the assumption of an unchanging series) provides a means of testing whether the residual of a particular order is capable of representing annual variation only. The mean correlations of successive yields between harvest 1, 2, 3 upto 6 years apart are significantly positive for every treatment as compared to the corresponding average value of expected correlation for an unchanging series. This indicates that the yields themselves do not correspond to an unchanging series, but show a time trend. The association between the neighbouring values approaches within limits of significance of the expected value as soon as the first degree polynomial curve is fitted to the mean yields and residuals taken. Thus it is inferred that the causes of variation in the mean yields are of two kinds only, viz. (i) steady deterioration and (ii) annual variation.

Deterioration of maize yields : The significant negative value of the linear regression coefficients (Table VI) indicates that there is a steady deterioration under all the treatments. The rate of deterioration in rape cake is significantly the highest, but it is comparatively less in farmyard manure, sulphate of ammonia and superphosphate (np), and the complete fertilizer treatment (npk). The rate of deterioration is least in the cases of sulphate of potash, superphosphate, and their combination and also control. It indicates, therefore, that the treatments which have given high yields exhausted the soil quickly and *vice versa*. Further consideration of the main effects and interactions of nitrogen (N) and phosphorus (P) and potash (K) in respect of steady deterioration (Table VII) shows that the rate of deterioration in the case of N is highly significant, whereas the main effect P and the interaction NP have significant rate of deterioration at 5 per cent level only. The rate of deterioration for the main effect K and interactions NK, PK and NPK is not significant. The treatments with potash do not deteriorate, as the yields given by these treatments are also poor. The soil is, therefore, least affected by the application of treatments with potash.

Relative variance : The annual variation for all the treatments are highly significant. It will, however, be observed from Fig. 3 that the annual variation is small for organic manures, but that for fertilizer treatments which include ammonium sulphate (n) as a component is not much more variable than for organic manures, whereas the annual variation is maximum under non-nitrogenous fertilizers, except superphosphate (p). The difference may be ascribed to high rainfall, especially during the monsoon, when the maize crop is grown, affecting the artificial fertilizers more than the organic manures. Similar conclusions were drawn by Mackenzie [1924] and Kalamkar [1933].

The greater relative variance of non-nitrogenous fertilizers is obvious. This may be due to the absence of nitrogen supply and washing out of the natural supply of soil nitrogen by heavy rainfall. Kalamkar [1935] also observed that the annual variation

was most on plots No. 7 and 11, receiving ashes of cow-dung and no manure respectively.

On the basis of these relative annual variance, it is possible to classify the treatments into three definite groups:

(i) Organic manures,

(ii) Nitrogenous fertilizer treatments and

(iii) Non-nitrogenous fertilizer treatments.

The two organic treatments, viz. rape cake and farmyard manure not only have greater mean yields, but the least relative variance. Organic manures act better in seasons of poor growth than in seasons of good growth. These manures have, therefore, a steadying effect on yields, thus tending to level up crop production and consequently reducing the variation in yield from season to season.

Summary and Conclusions

The grain yield data relating to maize from the Permanent Manurial Experiment, New Series, conducted at Pusa during 1932-1952 have been statistically examined in detail with a view to studying the effect of continuous application of manures and fertilizers every year to the same plot.

The yield data recorded for 20 years have been analysed to study, (i) the changes in the mean yields from year to year and cumulative effect of treatments, and (ii) the causes of variation in the yields.

1. The rape cake treatment gave significantly the highest yield of maize.

2. Farmyard manure (40 lb. N per acre), though gave significantly better yields than the control, did not show as good effects as the rape cake treatment.

3. The treatments np (sulphate of ammonia 40 lb. N+superphosphate 80 lb. P_2O_5 per acre), as well as npk, the complete fertilizer treatment (sulphate of ammonia 40 lb. N+superphosphate 80 lb. P_2O_5+sulphate of potash 50 lb. K_2O per acre) had also good effects and these did not differ significantly from farmyard manure.

4. Ammonium sulphate (n) alone did show superiority over control in the long term application, but it was inferior to organic manures and complete fertilizer treatments.

5. Superphosphate (p) or sulphate of potash (k) and their combination (pk) did not have any favourable effect on the yield of maize and these did not differ significantly from the control which recorded the poorest yields of maize.

6. The main response to nitrogen was highly significant and positive throughout the period. This confirmed that the mazie crop was benefited by the nitrogenous treatments, while the non-nitrogenous treatments had practically no effect on it.

7. All the treatments showed a significant rate of deterioration, but the treatments which gave higher yields had a higher rate of deterioration.

8. The only two kinds of variations present in the mean yields were, steady deterioration and annual variation.

9. The annual variation accounts for a greater proportion of the total variation than the deterioration.

10. The annual variation is small on all the plots receiving organic manures; the plots receiving complete artificials or n, np and nk are not much more variable than organic manures, but the annual variation of those plots which receive non-nitrogenous fertilizers is great.

ACKNOWLEDGMENTS

Our acknowledgments are due to Dr B. P. Pal, Director, Indian Agricultural Research Institute, New Delhi for his keen interest in the experiment and to Dr T. J. Mirchandani, Head of the Division of Agronomy for permission to examine the relevant data. The authors are also thankful to Shri V. N. Amble and Dr P. N. Saxena for suggestions and critical examination of the results and to Dr V. G. Panse, Statistical Adviser, Indian Council of Agricultural Research, New Delhi for going through the manuscript and helpful suggestions.

REFERENCES

Cochran, W. G. (1939). Long term agricultural experiments. *Roy. Stat. Soc. Suppl.*, **6** : 104-148

Fisher, R. A. (1921). An examination of the yield of dressed grain from Broadbalk. *J. agric. Sci.*, **11** : 107-135

Fisher, R. A. (1941). *Statistical methods for research workers.* Edinburgh

Kalamkar, R. J. (1933). A statistical examination of the yield of mangolds from Barnfield at Rothamsted. *J. agric. Sci.*, **23** : 161-175

——and Singh, S. (1935). A statistical examination of the yield of wheat at the Cawnpore Agricultural College Farm. *Indian J. agric. Sci.*, **5** : 346-354

Mackenzie, W. A. (1924). An examination of the yield of dressed grain from Hoos Field. *J. agric. Sci.*, **24** : 434-460

Menon, T. V. G. and Bose, S. S. (1937). A statistical study of the yields of the permanent manurials, Pusa. *Indian J. agric. Sci.*, **7** : 193-204

Raju, M. S. (1952). The role of organic manures and inorganic fertilizers in soil fertility. *Madras agric. J.*, **39** : 130-147

APPENDIX I

Analysis of variance for testing 'goodness of fit'

	Degrees of freedom	Mean squares	Variance ratio	Mean squares	Variance ratio	Mean squares	Variance ratio	Mean squares	Variance ratio	Mean squares	Variance ratio
		Treatment A (control)		*Treatment B* (F. Y. M.)		*Treatment C* (rape cake)		*Treatment D* (n)		*Treatment E* (k)	
Blocks	9	34·1500		31·3400		83·1500		72·9000		129·6900	
Linear regression or deterioration	1	958·0078		1795·0879		4356·0526		1451·2445		1050·9163	
Remainder (*a*)	18	117·6700	68·06**	209·1300	27·00**	247·3800	23·16**	176·2200	30·01**	125·2400	29·67**
Quadratic to quintic regression or slow changes	4	240·8842		222·6295		256·2867		216·2180		232·6862	
Remainder (*b*) or annual variation	14	82·4632	47·69**	205·2745	26·50**	244·8463	22·93**	164·7948	28·06**	94·5425	22·40**
Interaction (Blocks × regressions)	45	4·4210		12·3741		13·5125		7·6817		8·8024	
Error for testing remainders (*a*) and (*b*)	126	1·7290		7·7450		10·6802		5·8725		4·2214	
		Treatment F (p)		*Treatment G* (pk)		*Treatment H* (npk)		*Treatment I* (np)		*Treatment J* (nk)	
Blocks	9	64·0500		32·5200		92·4300		150·6100		80·3900	
Linear regression or deterioration	1	1303·7713		792·3961		2334·5119		2609·0496		1455·9151	
Remainder (*a*)	18	132·7800	38·01**	116·1100	48·73**	210·1600	31·86**	216·1000	29·63**	180·2500	42·06**
Quadratic to quintic regression or slow changes	4	185·8037		187·9018		185·0095		188·2714		280·2123	
Remainder (*b*) or annual variation	14	117·6391	33·68**	95·5944	40·12**	217·3550	32·96**	224·0543	30·72**	151·6936	35·42**
Interaction (Blocks × regressions)	45	8·9772		6·1075		12·5040		12·5111		6·3831	
Error for testing remainders (*a*) and (*b*)	126	3·4930		2·3828		6·5954		7·2939		4·2832	

**Significant at 1 per cent level

APPENDIX II

Correlation of neighbouring values and residuals after fitting Linear regressions

k years apart	Correlation between harvests	Transformed value of (r)	Standard error	Correlation between residuals after fitting linear regressions	Transformed value of (r)
	r	Z	S. E.	*r*	*Z*
			Treatment A (control)		
1	0·0680	0·0680	±0·2500	—0·3196	—0·3312
2	0·3426	0·3578	±0·2581	0·0272	0·0272
3	0·4869	0·5325	±0·2672	0·2574	0·2633
4	—0·0240	—0·0240	±0·2773	—0·3072	—0·3197
5	0·1990	0·2028	±0·2886	—0·0263	—0·0263
6	—0·1293	—0·1300	±0·3015	—0·2857	—0·2939
Mean		0·1802			—0·1100
Expectation		—0·0645			—0·1036
Difference		0·2447*			—0·0064
S. Ed.		±0·1111			±0·1111
			Treatment B (F. Y. M.)		
1	0·0575	0·0575	±0·2500	—0·3366	—0·3523
2	0·1393	0·1402	±0·2581	—0·2964	—0·3056
3	0·4930	0·5400	±0·2672	0·2971	0·3064
4	0·1151	0·1156	±0·2773	—0·1925	—0·1949
5	0·2381	0·2428	±0·2886	0·0422	0·0422
6	—0·1246	—0·1253	±0·3015	—0·2361	—0·2406
Mean		0·1682			—0·1309
Expectation		—0·0645			—0·1036
Difference		0·2327*			—0·0273
S. Ed.		±0·1111			±0·1111

APPENDIX II—*contd.*

k years apart	Correlation between harvests	Transformed value of (r)	Standard error	Correlation between residuals after fitting linear regressions	Transformed Value of (r)
	r	Z	E	*r*	*Z*
		Treatment C (rape cake)			
1	0·3465	0·3615	±0·2500	−0·2931	−0·3020
2	0·3464	0·3615	±0·2581	−0·3153	−0·3264
3	0·6097	0·7084	±0·2672	0·3122	0·3230
4	0·3644	0·3880	±0·2773	−0·1257	−0·1264
5	0·3253	0·3324	±0·2886	−0·0531	−0·0531
6	0·1400	0·1591	±0·3015	−0·1488	−0·1499
Mean		0·3939			−0·1128
Expectation		−0·0645			−0·1036
Difference		0·4584**			−0·0092
S. Ed.		±0·1111			±0·1111
		Treatment D (n)			
1	0·0185	0·0185	±0·2500	−0·3453	−0·3601
2	0·3162	0·3274	±0·2581	−0·0354	−0·0354
3	0·3815	0·3918	±0·2672	0·1397	0·1406
4	0·1150	0·1155	±0·2773	−0·3389	−0·3528
5	0·1036	0·1039	±0·2886	−0·1003	−0·1006
6	−0·0488	−0·0488	±0·3015	−0·1470	−0·1481
Mean		0·1593			−0·1451
Expectation		−0·0645			−0·1036
Difference		0·2238*			−0·0415
S. Ed.		±0·1111			±0·1111

APPENDIX II—*contd.*

k years apart	Correlation between harvests	Transformed value of (r)	Standard error	Correlation between residuals after fitting linear regressions	Transformed value of (r)
	r	Z	S. E.	r	Z
		Treatment E (k)			
1	−0·0309	−0·0309	±0·2500	−0·3590	−0·3757
2	0·4020	0·4261	±0·2581	0·0890	0·0908
3	0·3994	0·4230	±0·2672	0·1545	0·1558
4	0·0599	0·0600	±0·2773	−0·2211	−0·2248
5	0·1336	0·1344	±0·2886	−0·0703	−0·0703
6	−0·0825	−0·0825	±0·3015	−0·2105	−0·2136
Mean		0·1643			−0·1060
Expectation		−0·0645			−0·1036
Difference		0·2288*			−0·0024
S. Ed.		±0·1111			±0·1111
		Treatment F (p)			
1	−0·0086	−0·0086	±0·2500	−0·4602	−0·5001
2	0·3627	0·3800	±0·2581	0·0110	−0·0110
3	0·4366	0·4680	±0·2672	0·1915	0·1939
4	0·1119	0·1123	±0·2773	−0·2049	−0·2078
5	0·2368	0·2414	±0·2886	−0·0058	−0·0058
6	−0·0070	−0·0070	±0·3015	−0·1904	−0·1928
Mean		0·2024			−0·1236
Expectation		−0·0645			−0·1036
Difference		0·2669*			−0·0200
S. Ed.		±0·1111			±0·1111

APPENDIX II—*contd.*

k years apart	Correlation between harvests	Transformed value of (r)	Standard error.	Correlation between residuals after fitting linear regressions	Transformed value of (r)
	r	Z	S. E.	r	Z
		Treatment G (pk)			
1	0·1012	0·1015	±0·2500	−0·4177	−0·4449
2	0·2776	0·2851	±0·2581	−0·0151	−0·0151
3	0·4112	0·4371	±0·2672	0·2256	0·2295
4	0·0413	0·0413	±0·2773	−0·1939	−0·1963
5	0·1595	0·1609	±0·2886	−0·0277	−0·0277
6	−0·1112	−0·1116	±0·3015	−0·2329	−0·2372
Mean		0·1637			−0·1188
Expectation		−0·0645			−0·1036
Difference		0·2282*			−0·0152
S. Ed.		±0·1111			±0·1111
		Treatment H (npk)			
1	0·0850	0·0850	±0·2500	−0·3993	−0·4229
2	0·2937	0·3026	±0·2581	−0·1616	−0·1631
3	0·5398	0·6039	±0·2672	0·3096	0·3201
4	0·0382	0·0382	±0·2773	−0·3573	−0·3738
5	0·2485	0·2538	±0·2886	0·0187	0·0187
6	0·0367	0·0367	±0·3015	−0·0926	−0·0928
Mean		0·2259			−0·1282
Expectation		−0·0645			−0·1036
Difference		0·2904*			−0·0246
S. Ed.		±0·1111			±0·1111

APPENDIX II—*contd.*

k Years apart	Correlation between harvests	Transformed value of (r)	Standard error	Correlation between residuals after fitting linear regressions	Transformed value of (r)
	r	Z	S. E.	r	Z
			Treatment I (np)		
1	0·1565	0·1578	±0·2500	−0·3501	−0·3656
2	0·1468	0·1479	±0·2581	−0·2219	−0·2257
3	0·5217	0·5786	±0·2672	0·2562	0·2620
4	0·1779	0·1798	±0·2773	−0·2265	−0·2305
5	0·2068	0·2098	±0·2886	−0·0671	−0·0671
6	0·0731	0·0731	±0·3015	−0·0674	−0·0674
Mean		0·2284			−0·1248
Expectation		−0·0645			−0·1036
Difference		0·2929*			−0·0212
S. Ed.		±0·1111			±0·1111
			Treatment J (nk)		
1	0·0781	0·0781	±0·2500	−0·2837	−0·2917
2	0·3203	0·3320	±0·2581	−0·0255	−0·0255
3	0·3801	0·4001	±0·2672	0·1429	0·1439
4	0·1397	0·1461	±0·2773	−0·4484	−0·4827
5	0·1356	0·1364	±0·2886	−0·0370	−0·0370
6	−0·1345	−0·1353	±0·3015	−0·2082	−0·2113
Mean		0·1713			−0·1491
Expectation		−0·0645			−0·1036
Difference		0·2348*			−0·0455
S. Ed.		±0·1111			±0·1111

**Significant at 1 per cent level
*Significant at 5 per cent level

REVIEWS

SMALL FRUIT CULTURE

BY

J. S. SHOEMAKER

(Published by McGraw-Hill & Co. Inc. New York/Toronto/London, 3rd Edition, 1955, pp. 447. Price $ 6·50)

THE book on small fruit culture by Prof. J. S. Shoemaker contains six chapters. Each chapter gives detailed account of grape culture, strawberry culture, bramble culture, currant and gooseberry culture, blue berry culture and cranberry culture. The information covers all aspects starting from a brief history and followed by a list and description of varieties, propagation methods, cultural practices, harvesting and marketing, and insect pests and diseases and their control. The material has been collected from a vast but scattered literature on small fruits. In addition to this, the growers' experience, the suggestions from specialists and the valuable experience of the author are also included.

More than 200 new references have been added to this new edition bringing the total number to 621. This shows the great progress that has been made during recent years in the culture of small fruits. The number of illustrations has also been increased from 52 to 75 in this edition.

Newer varieties of different fruits, important cultural and irrigation methods, and up-to-date information on training methods are some of the new features of this edition.

The fact that the author of this valuable book had to revise it for the third time and reprint the first two editions four times since it was first published in 1934 speaks of the great popularity that this book enjoys. Although the general set up of the text remains much the same as in earlier editions, the present one is a definite improvement inasmuch as many new and important developments that had taken place during the last decade have been incorporated.

The general get-up of the book is indeed excellent in the present edition. Although the price of this edition has almost been doubled it is more than justified by the art paper used, the photographs, the illustrations, the new headings and sub-headings used and the beautiful printing that have given a new shape to this book.

The author, Dr. Shoemaker is an experienced professor of horticulture at the Ontario Agriculture College, Guelph, Ontario (Canada) and a horticulturist of great eminence. He has presented the research work so far carried out on small fruits in a simple and lucid style. The book is considered to be of great utility not only in institutions, research stations and Universities, but also for growers interested in the cultivation of small fruits. (S. S.).

COMMERCIAL FRUITS OF INDIA

With special reference to Western India

BY G. S. CHEEMA, S. S. BHAT and K. C. NAIK

(Macmillan & Compay Ltd., Calcutta—Bombay—Madras—London, 1954, *pp. 422. Price Rs. 18)*

THE existing paucity of literature on Indian horticulture has been partially met by the publication of this book on the commercial fruits of India. Although based on the information gathered in the Southern and Western parts of the country, the book has an all-India appeal and value.

Three experienced horticulturists have joined hands to write a comprehensive account of some important fruits grown in the country. The book comprises 10 chapters, each devoted to banana, mango, citrus fruits, guava, promegranate, papaya, grape, sapota, fig and *ber*. Each chapter is self-contained giving complete information on different aspects such as importance of the fruits, its origin, distribution, soil, climate, propagation, cultural practises, varieties, harvesting marketing, pests, diseases, food value and bibliography. Maps giving the distribution of acreage under different fruits have also been included. This system of arrangement may lead to a certain amount of repetition, but has facilitated the work of the casual reader who can find complete information about each fruit in one place.

The book gives an authoritative account of the various practices which have been practised and found useful through the long experience of the authors themselves. The practices followed in other countries of the world have also been referred to at appropriate places. While going through the text, however, one feels as if there is discontinuity of ideas at some places. This is probably due to the fact that all the available literature on the subject under discussion, whether relevant to it or not, has been included in one place. All the same, this information gives the reader an idea of what is being done in other countries.

The material presented in the book relates to the period ending 1948 and many a new findings have came to light since then. It may be necessary on this account for the authors to revise this book after a few years. There are a few minor mistakes. These however, do not depreciate the merits of the book. It can be recommended for the use of horticulturists, fruit growers and nurserymen as a practical guide. It may also serve as a suitable text and reference book. (S.S.).

MGIPC—M—47AR/55—20-4-56—1,125.

AN ANNOUNCEMENT

JOHN MURRARY TRAVELLING STUDENTSHIP IN OCEANO-GRAPHY AND LIMNOLOGY

The Council of the Royal Society is prepared to receive applications for the John Murrary Travelling Studentship in Oceanography and Limnology. Particulars and application forms may be obtained from The Assistant Secretary, Royal Society, Burlington House, Piccadilly, London, WI.

The Editorial Board in its work of examining papers received for publication is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Indian Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instruction to Authors

Article intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to authors, names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown-quarto (about $7\frac{1}{2}$ in. $\times 9\frac{5}{8}$ in. cut) no text figure, when printed should exceed $4\frac{1}{2}$ in. $\times 5$ in. Figures for plates should be so planned as to fill a crown quarto page, the maximum space available for figures being $5\frac{1}{2}$ in. $\times 8$ in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.

PRINTED IN INDIA BY THE MANAGER, GOVERNMENT OF INDIA PRESS, CALCUTTA
AND PUBLISHED BY THE MANAGER OF PUBLICATIONS, CIVIL LINES, DELHI 1956